PROPOSED

TOTAL MAXIMUM DAILY LOADs (TMDLs)

For

Fecal Coliform

In

303(d) Listed Streams in The Altamaha River Basin

August 30, 2001

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LIST OF ABBREVIATIONS

BMP	Best Management Practices
CFS	Cubic Feet per Second
DEM	Digital Elevation Model
DMR	Discharge Monitoring Report
DNR	Department of Natural Resources
DWPC	Division of Water Pollution Control
EPA	Environmental Protection Agency
EPD	Environmental Protection Division (State of Georgia)
GIS	Geographic Information System
HSPF	Hydrological Simulation Program - FORTRAN
HUC	Hydrologic Unit Code
LA	Load Allocation
MGD	Million Gallons per Day
MOS	Margin of Safety
MPN	Most Probable Number
MRLC	Multi-Resolution Land Characteristic
NPDES	National Pollutant Discharge Elimination System
NPSM	Nonpoint Source Model
NRCS	Natural Resources Conservation Service
Rf3	Reach File 3
RM	River Mile
STORET	STORage RETrieval database
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WCS	Watershed Characterization System
WLA	Waste Load Allocation

SUMMARY
Proposed Total Maximum Daily Loads (TMDLs)
303(d) Listed Streams in Altamaha River Basin - HUC 03070106

State: Georgia

Counties: Wayne and Long

Major River Basin: Altamaha River

Constituent(s) of Concern: Fecal Coliform Bacteria

Summary of 303(d) Listed Waterbody Information and Allocation by Stream Segment

Stream Name	Segment Description	Hydrologic Unit(s)	Use Classification	Segment Length (miles)	Drainage Area ($miles^2$)	WLA (#/30 days)	LA (#/30 days)	MOS	TMDL (#/30 days)
Doctors Creek	Upstream of Jones Creek	030701060404 030701060405	Fishing	5	67.8	0	1.87×10^{11}	2.07×10^{10}	1.87×10^{11}
Goose Creek	U/S Rd. S1922 to Little Goose Creek	030701060307	Fishing	8	77.9	0	1.45×10^{11}	1.61×10^{10}	1.45×10^{11}

Note: Current and future discharges shall be permitted at or below the water quality standard for fecal coliform bacteria of 200-counts/100 ml.

Applicable Water Quality Standard for Fishing use classification:

Section 391-3-6-.03 (6) of the *State of Georgia Rules and Regulations for Water Quality Control, Chapter 391-3-6 Revised, July, 2000:*

May through October - fecal coliform is not to exceed a geometric mean of 200 per 100 ml based on at least four samples collected from a given sampling site over a 30-day period at intervals not less than 24 hours. Should water quality and sanitary studies show fecal coliform levels from non-human sources exceed 200 per 100 ml (geometric mean) occasionally, then the allowable geometric mean fecal coliform shall not exceed 300 per 100 ml in lakes and reservoirs and 500 per 100 ml in free flowing freshwater streams.

November through April - fecal coliform is not to exceed a geometric mean of 1,000 per 100 ml based on at least four samples collected from a given sampling site over a 30-day period at intervals not less than 24 hours and not to exceed a maximum of 4,000 per 100 ml for any sample. The geometric mean standard is the target value for the TMDLs

TMDL Development - Analysis/Modeling:

The Hydrologic Simulation Program Fortran (HSPF) watershed model was used to develop these TMDLs. An hourly time step was used to simulate hydrologic and water quality conditions with results expressed as daily averages. Fecal coliform loading rates from the various sources are based on county population estimates and literature values. A conservative estimate of in-stream decay was assumed in the model. A ten-year time period was used to simulate water quality conditions in the303(d) listed streams. This time period cover a range of precipitation events from which critical conditions were determined for estimating the TMDLs.

PROPOSED
FECAL COLIFORM TOTAL MAXIMUM DAILY LOADS (TMDLs)
for 303(d) listed stream segments in the
ALTAMAHA RIVER BASIN

1.0 INTRODUCTION

Section 303(d) of the Clean Water Act requires each state to list those waters within its boundaries for which technology based effluent limitations are not stringent enough to protect any water quality standard applicable to such waters. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. This allows water quality based controls to be developed and implemented in an effort to reduce pollution, and restore and maintain compliance with water quality standards.

The TMDLs proposed in this report represent the first phase of a long-term process to reduce fecal coliform loading to meet water quality standards in the Altamaha River basin. Implementation strategies will be reviewed and the TMDLs will be refined as necessary in the next phase (next five-year cycle). The phased approach will support progress toward water quality standards attainment in the future. In accordance with USEPA TMDL guidance (EPA, 1991), these TMDLs may be revised based on results of future monitoring and source characterization data efforts.

The reduction scenario proposed for the TMDLs represent one possible allocation scenario that can be used to meet water quality standards. Stakeholders in the impaired watersheds may choose other allocation scenarios to meet the required load reductions.

2.0 WATERSHED DESCRIPTION

The Altamaha River is formed by the confluence of the Ocmulgee and Oconee Rivers in Southeastern Georgia and flows in a southeastern direction to the Atlantic Ocean (Figure 1). The Altamaha River basin includes two United States Geologic Survey (USGS) eight-digit hydrologic units, HUC 03070107 (Ohoopee River watershed), and HUC 03070106 (Altamaha River watershed).

The Altamaha River basin falls within the Level III Southeastern Plains (65) and Southern Coastal Plains (75) ecoregions. The Ohoopee River watershed is located primarily in the Level IV Atlantic Southern Loam Plains (65l) subecoregion, with small portions of the headwaters extending up into the Coastal Plain Red Uplands (65k) subecoregion. The Altamaha River watershed is a multifaceted watershed with outlying portions of the watershed located in the Level IV Atlantic Southern Loam Plains (65l) and Sea Island Flatwoods (75f) subecoregions, and coastal portions (within approximately 15 miles of the coast) of the watershed located in the Sea Islands/Coastal Marsh (75j) subecoregion. There is also a corridor, running the length of the river in all non-coastal portions of the watershed and extending (approximately) one to three miles inland on each side of the river, which lies in the Southeastern Floodplains and Low Terraces (65p) and Floodplains and Low Terraces (75i) subecoregions. Typical characteristics for these subecoregions are as follows:

- Coastal Plain Red Uplands (65k) - this region contains mostly well drained soils composed of red sand and clay; the majority of the land is utilized as cropland or pasture.

- Atlantic Southern Loam Plains (65l) - this region contains soils ranging from poorly drained to excessively drained; longleaf pine, oak and some distinctive evergreen shrubs are common vegetation.

- Southeastern Floodplains and Low Terraces (65p) – this region contains large sluggish rivers and backwaters with ponds, swamps and oxbow lakes; terraces are typically covered by oak forests, while forests of bald cypress and water tupelo grow in the swamps and river areas.

- Sea Island Flatwoods (75f) – this region contains poorly drained, flat plains with spodosols and other wet soils common; loblolly and slash pine plantation land covers much of the region, with cypress, sweetgum, blackgum water oak and willow oak common in wet areas.

- Sea Islands/Coastal Marsh (75j) – this region contains the lowest elevations in Georgia and is a highly dynamic environment; organic, clayey soils often occur in the numerous freshwater, brackish and salt marshes; marshes are covered with various species of cordgrass, salt grass and rushes, while live oaks, red cypress, slash pines and cabbage palmettos cover the mainland areas.

- Floodplains and Low Terraces (75i) - this region contains floodplains and bottomland composed of stream alluvium and terrace deposits of sand, silt, clay and gravel, along with some organic muck and swamp deposits; large sluggish rivers and backwaters with ponds, swamps and oxbow lakes.

The Altamaha River basin contains approximately 6,250 miles of Reach File 3 (Rf3) level streams and drains a total area of approximately 2,744 square miles. Watershed land use distribution is based on the Multi-Resolution Land Characteristic (MRLC) databases derived from Landsat Thematic Mapper digital images from the period 1990-1994. Land use in the Altamaha River basin is summarized in Table 1, and shown in Figure 2.

For purposes of calculating fecal coliform loading rates applied to each land coverage, the MRLC data were summarized into six broad categories: urban pervious, urban impervious, cropland, pastureland, forest and, wetlands. Fecal coliform loading rates were assigned to all land coverages based on the types of sources in each watershed and literature values (NCSU, 1994; EPA, 2001). The loadings from forest and wetlands were assumed to be background. The loadings from urban, cropland, and pasturelands were subject to reductions in the TMDL analysis.

3.0 PROBLEM DEFINITION

EPA Region 4 approved Georgia's final 2000 303(d) list on August 28, 2000. This 303(d) list was then updated for the Altamaha, Ocmulgee, and Oconee River Basins and was finalized and approved by EPA Region 4 in June, 2001. The list identified the waterbodies for the Altamaha River basin shown in Table 2, as either not supporting or partially supporting designated use classifications, due to exceedence of water quality standards for fecal coliform bacteria. Fecal coliform bacteria are used as an indicator of the potential presence of pathogens in a stream. The objective of this study is to develop fecal coliform TMDLs for 303(d) listed waterbodies in the Altamaha River basin. In accordance with TMDL guidelines (EPA, 1991), the TMDLs are based on readily available published.

Pursuant to the Consent Decree in the case of Sierra Club v. EPA, 1:94-cv-2501-MHS (N.D. GA), the State or EPA shall develop TMDLs for all waterbodies on the State of Georgia's current 303(d) List by a prescribed schedule. On June 30, 2001, The Georgia Environmental Protection Division (EPD) proposed TMDLs for Milligan Creek and Oconee, located in the Altamaha River Basin and impaired for fecal coliform bacteria. The TMDLs for Doctors Creek and Goose Creek are included in this report.

4.0 TARGET IDENTIFICATION

Doctors Creek and Goose Creek have designated use classifications of fishing. The fecal coliform water quality criteria for protection of the fishing use classification is established by the *State of Georgia Rules and Regulations for Water Quality Control, Chapter 391-3-6 Revised, July, 2000*. These criteria will be used as the target level for fecal coliform TMDL development for all listed segments in the Altamaha River basin.

Section 391-3-6-.03 (6) of the *State of Georgia Rules and Regulations for Water Quality Control, Chapter 391-3-6 Revised, July, 2000*, states that during the months of May through October, when water contact recreation activities are expected to occur, fecal coliform is not to exceed a geometric mean of 200 per 100 ml based on at least four samples collected from a given sampling site over a 30-day period at intervals not less than 24 hours. Should water quality and sanitary studies show fecal coliform levels from non-human sources exceed 200/100 ml (geometric mean) occasionally, then the allowable geometric mean fecal coliform shall not exceed 300 per 100 ml in lakes and reservoirs and 500 per 100 ml in free flowing freshwater streams. For the months of November through April, fecal coliform is not to exceed a geometric mean of 1,000 per 100 ml based on at least four samples collected from a given sampling site over a 30-day period at intervals not less than 24 hours and not to exceed a maximum of 4,000 per 100 ml for any sample. The geometric mean standard is the target for the TMDLs. An implicit and explicit MOS is applied to this standard during development of the TMDLs, as detailed in Section 8.3 of this report.

The geometric mean standard is the primary target value for the TMDLs as the geometric mean is a better representation of average conditions in the stream than the instantaneous standard. The instantaneous standard is difficult to model and insufficient data are available to calibrate the water quality model to this standard. By meeting the geometric mean standard compliance with the instantaneous standard is usually obtained. The TMDLs are expressed in terms of a 10-year geometric mean plot. The purpose of the ten-year period is to show that the proposed reductions comply with the geometric mean standards and to illustrate standards have been met for all seasons. To address uncertainty in the model, a margin of safety (MOS) of 10 percent of the load allocation is included in the TMDLs.

5.0 WATER QUALITY ASSESSMENT AND DEVIATION FROM TARGET

Compliance with the applicable fecal coliform water quality criteria was assessed for each 303(d) listed waterbody, based on water quality data collected from the monitoring stations listed in Table 3.

Water quality data collected during calendar year 1999 for the 303(d) listed stream segments are summarized in Table 4. A geometric mean in excess of 200 counts per 100 milliliters during the period May – October, or in excess of 1000 counts per 100 milliliters during the period November – April, provides a basis for adding a stream segment to the 303(d) List. A single sample in excess of 4000 counts per 100 milliliters can also provide a basis for adding a stream segment to the 303(d) List.

6.0 SOURCE ASSESSMENT

An important part of the TMDL analysis is the identification of source categories, source subcategories, or individual sources of fecal coliform bacteria in the watershed and the amount of loading contributed by each of these sources. Sources are broadly classified as either point or nonpoint sources. Point sources comprise the waste load allocation (WLA) component of the TMDL whereas nonpoint sources comprise the load allocation (LA) component of the TMDL.

A point source can be defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. Point source discharges of industrial wastewater and treated sanitary wastewater must be authorized by National Pollutant Discharge Elimination System (NPDES) permits. NPDES permitted facilities discharging treated sanitary wastewater are considered primary point sources of fecal coliform bacteria.

Nonpoint sources of fecal coliform bacteria are diffuse sources that cannot be identified as entering a waterbody through a discrete conveyance at a single location. These sources generally, but not always, involve accumulation of fecal coliform bacteria on land surfaces and washoff as a result of storm events. Typical nonpoint sources of fecal coliform bacteria include:

- Wildlife
- Land application of agricultural manure
- Livestock grazing
- Leaking septic systems
- Urban development (including leaking sewer collection lines)
- Animals having access to streams

6.1 Point Sources

There are no permitted point source discharges of fecal coliform bacteria in either the Doctors Creek or Goose Creek watersheds.

6.2 Nonpoint Source Assessment

6.2.1 Wildlife

Wildlife deposit feces onto land surfaces where it can be transported during storm events to nearby streams. In the water quality model, the wildlife fecal coliform contribution is accounted for in the deer population, as population estimates of raccoons, waterfowl, and other wildlife are not readily available. The deer population is estimated to be 30 to 45 animals per square mile in this area (Georgia WRD, 1999). The upper limit of 45 deer per square mile has been chosen to account for deer and all other wildlife present in the watershed. It is assumed that the wildlife population remains constant throughout the year, and that wildlife is uniformly distributed on all land classified in the MRLC database as forest, pasture, cropland, and wetlands. The fecal coliform concentration assigned to deer is approximately 5.0×10^8 counts/animal/day (EPA, best professional judgement). The resulting load attributed to wildlife is about 3.5×10^7 counts/acre-day.

6.2.2 Agricultural Animals

Agricultural animals are also a potential source of several types of fecal coliform loading to streams in the Altamaha River basin. Livestock data are reported by county and published by the USDA in the Census of Agriculture (USDA, 1997). The available livestock data include population estimates for cattle, beef cows, dairy cows, hogs, sheep, and poultry (broilers and layers). Livestock data for the counties comprising the 303 (d) listed streams are shown in Table 5. Cattle numbers reported in the census data also represent other breeds of cattle and calves in addition to dairy and beef. Assumptions regarding agricultural animals and resource management practices were provided by NRCS (USDA, 2001) and are summarized as follows:

- As with wildlife, agricultural livestock grazing on pastureland or forestland deposit their feces onto land surfaces where it can be transported during storm events to nearby streams.

- Confined livestock operations also generate manure, which can be applied to pastureland and cropland as a fertilizer. Processed agricultural manure from confined hog, dairy cattle, and some poultry operations is generally collected in lagoons and applied to land surfaces during the growing season, at rates which often vary on a monthly basis. Data sources for agricultural animals are tabulated by county and are based on information obtained from the Census of Agriculture (USDA, 1997). Fecal coliform loading rates for livestock in the watershed are estimated to be: 1.06 x 10^{11} counts/day/beef cow, 1.24 x 10^{10} counts/day/hog, 1.04 x 10^{11} counts/day/dairy cow, 1.38 x 10^{8} counts/day/layer chicken, and 1.22 x 10^{10} counts/day/sheep (NCSU, 1994).

- Agricultural livestock and other unconfined animals (i.e., deer and other wildlife) also often have direct access to streams that pass through pastures. Feces deposited into these streams by grazing animals are included in the water quality model as a point source having constant flow and concentration. To calculate the amount of fecal coliform bacteria introduced into streams by cattle, it is assumed that 50 percent of the beef cows in the watershed have access to the streams, and of those, 25 percent defecate in or near the stream banks during a portion of the day (personal communication, EPA, Georgia Agribusiness Council, NRCS, University of Georgia, et. al.). The resulting percentage of time fecal coliform bacteria is discharged into the stream from grazing animals is 0.025 percent.

Assumptions regarding manure management practices for specific agricultural livestock operations areas are similar to those used to develop the TMDLs for the South Georgia Four Basins in 2000 and include:

- Poultry litter is normally piled for a period before it is applied to the land. Within the Altamaha River basin it is estimated that approximately 60 percent of poultry litter (i.e., broiler and layers) is applied to pastureland and 40 percent is applied to cropland. It is assumed that the poultry litter is applied primarily during the period between March and October (inclusive), and that application rates vary monthly.

- Hog farms in the Altamaha River basin operate by confining the animals or allowing them to graze in small pastures or pens. It is assumed that all of the hog manure produced by either farming method is applied to available pastureland, with negligible amounts applied to cropland. Application rates of hog manure to pastureland vary monthly according to management practices. Manure is applied during the period between March and October (inclusive).

- On dairy farms, the cows are confined for a limited period each day during which time they are fed and milked. This is estimated to be four hours per day for each dairy cow. It is assumed that 60 percent of manure collected during confinement is applied to pastureland and 40 percent is applied to cropland. It is also assumed that the dairy cow manure is applied during the period between February and October (inclusive), as well as in November. Application rates vary monthly according to management practices.

- Beef cattle are assumed to be in pasture year round. Therefore, beef cow manure is applied only to pastureland and at a constant monthly rate. This rate varies between watersheds, as the rate is a function of the number of beef cows in the watershed.

6.2.3 Leaking Septic Systems

Fecal coliform loading in the Altamaha River basin may also be attributed to septic system failures. Loading rates are based on estimates from county census data of people in each listed stream watershed utilizing septic systems and literature values for fecal coliform concentrations in human waste. Septic population estimates were updated based on a county-by-county survey conducted by EPD in April-May 2001. It is estimated that there are approximately 2.37 people per household on septic systems (EPA, best professional judgment). For modeling purposes, EPA assumed that ten percent of the septic systems in the watershed leak. Leaking septic systems are included in the water quality model as a point source having constant flow and concentration. The average fecal coliform concentration of the septic system wastewater reaching a stream was assumed to be 1 x 10^4 counts per 100 ml (EPA, 2001).

6.2.4 Urban Development

Fecal coliform loading from urban areas is potentially attributable to multiple sources including storm water runoff, illicit discharges of sanitary waste, runoff from improper disposal of waste materials, leaking septic systems, and domestic animals.

7.0 ANALYTICAL APPROACH

Establishing the relationship between in-stream water quality and source loading is an important component of TMDL development. It allows the determination of the relative contribution of sources to total pollutant loading and the evaluation of potential changes to water quality resulting from implementation of various management options. This relationship can be developed using a variety of techniques ranging from qualitative assumptions based on scientific principles to numerical computer modeling. In this section, the numerical modeling techniques developed to simulate fecal coliform bacteria fate and transport in the watershed are discussed.

7.1 Model Selection

A dynamic computer model was selected for fecal coliform analysis in order to: a) simulate the time varying nature of fecal coliform deposition on land surfaces and transport to receiving waters; b) incorporate seasonal effects on the production and fate of fecal coliform bacteria; and c) identify the critical condition for the TMDL analysis. Several computer-based tools were also utilized to generate input data for the model.

The Nonpoint Source Model (NPSM) is a watershed model capable of simulating nonpoint source runoff and associated pollutant loadings, account for point source discharges, and performing flow and water quality routing through stream reaches. NPSM is based on the Hydrologic Simulation Program - Fortran (HSPF). In these TMDLs, NPSM was used to simulate point source discharges, simulate the deposition and transport of fecal coliform bacteria from land surfaces, and compute the resulting water quality response. In-stream decay of fecal coliform bacteria is included in the model at a rate of 0.048 per hour. This rate represents the median value reported in Lombardo (1972) who reported decay rates from 0.008 per hour to 0.13 per hour.

In addition to NPSM, the Watershed Characterization System (WCS), a geographic information system (GIS) tool, was used to display, analyze, and compile available information to support water quality model simulations. This information includes land use categories, point source dischargers, soil types and characteristics, population data (human and livestock), and stream characteristics. Results of the WCS characterization are input to a spreadsheet developed by Tetra Tech, Inc. to estimate NPSM input parameters associated with fecal coliform buildup (loading rates). The spreadsheet is also used to estimate direct sources of fecal coliform loading to water bodies from leaking septic systems and animals having access to streams. Information from the WCS and spreadsheet tools were used as initial input for variables in the NPSM model.

7.2 Model Set Up

The Altamaha River basin was divided into three projects with each project containing between 7 and 13 delineated subwatersheds. The delineated watersheds for Doctors Creek and Goose Creek correspond to the 12 digit HUCs established by the State of Georgia and are shown in Figure 3. Watershed delineation was based on the Reach File 3 (Rf3) stream coverage and Digital Elevation Model (DEM) data. This discretization allows management and load reduction alternatives to be varied by subwatershed.

An important factor influencing model results is the precipitation data contained in the meteorological data file used in the simulation. The pattern and intensity of rainfall affects the build-up and wash-off of fecal coliform bacteria from the land into the streams, as well as the dilution potential of the stream. Precipitation data from a weather station in close proximity to a watershed was used in the simulations.

7.3 Model Calibration

Calibration of the watershed model included both hydrology and water quality components. The hydrology calibration was performed first and involved adjustment of the model parameters used to represent the hydrologic cycle until acceptable agreement was achieved between simulated flows and historic stream flow data from a USGS stream gaging station in the watershed for the same period of time. Model parameters adjusted include: evapotranspiration, infiltration, upper and lower zone storage, groundwater storage, recession, losses to the deep groundwater system, and interflow discharge. Hydrology calibrations are presented in Appendix A, along with USGS gages used for the flow calibrations. Calibrated models were then subjected to model validation to ensure that generated model streamflows for each of the impaired segments were acceptable.

The model was also calibrated for water quality. Appropriate model parameters were adjusted to obtain acceptable agreement between simulated instream fecal coliform concentrations and observed data collected at the sampling stations indicated in Table 3. Water quality calibrations for the listed streams are presented in Appendix B.

8.0 DEVELOPMENT OF TOTAL MAXIMUM DAILY LOAD

The TMDL process quantifies the amount of a pollutant that can be assimilated in a waterbody, identifies sources of the pollutant, and recommends regulatory or other actions to be taken to achieve compliance with applicable water quality standards based on the relationship between pollution sources and in-stream water quality conditions. A TMDL can be expressed as the sum of all point source loads (WLAs), nonpoint source loads (LAs), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$\text{TMDL} = \Sigma\ \text{WLAs} + \Sigma\ \text{LAs} + \text{MOS}$$

The objective of a TMDL is to allocate loads among known pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. 40 CFR §130.2 (i) states that TMDLs can be expressed in terms of mass per time (e.g., pounds per day), toxicity, or other appropriate measure. For fecal coliform bacteria, the TMDLs are expressed as counts per 30 days. The TMDL represents the maximum load that can occur over a 30-day period while maintaining water quality standards.

8.1 Critical Conditions

The critical condition for nonpoint source fecal coliform loading is an extended dry period followed by a rainfall runoff event. During the dry weather period, fecal coliform bacteria builds up on the land surface, and is washed off by rainfall. The critical condition for point source loading occurs during periods of low stream flow when dilution is minimized. Both conditions are simulated in the water quality model.

A definitive time period was used to simulate a continuous 30-day geometric mean concentration to compare to the target. For TMDLs in the Altamaha Basin, this time period is ten years and covers a range of hydrological conditions that included both low and high stream flows.

The simulated 30-day geometric mean concentrations for existing conditions are presented in C. From these figures, critical conditions can be determined. The 30-day critical period in the model is the period preceding the largest simulated violation of the geometric mean standard (EPA, 1991). During periods where the model predicted extremely low stream flows, the model often became unstable and exhibited extreme positive or negative spikes. These portions of the simulation were excluded from consideration of the critical period. Meeting water quality standards during the critical period ensures that water quality standards can be achieved throughout the reviewed time period. For the listed segments in the Altamaha River basin, the critical period used in development of the TMDLs is given in Table 6.

8.2 Existing Conditions

The existing fecal coliform load for each of the 303(d) listed waterbodies in the Altamaha River basin was determined in the following manner:

- The calibrated model, corresponding to the portion of the Altamaha River basin that is upstream of the pour point of the listed waterbody segment was run for a time period that included the critical condition. This critical time period is provided for each listed segment in Table 6.

- The existing fecal coliform load for each listed segment is represented as the sum of the daily discharge load of other modeled direct sources (e.g., other direct sources such as animal access to streams, illicit discharges of fecal coliform bacteria, failing septic systems, or leaking sewer collection lines), and the daily fecal coliform load indirectly going to surface waters from all land uses (e.g., surface runoff), over the 30 day critical period.

- Point source loads are not an issue in either Doctors Creek or Goose Creek as neither watershed has any NPDES facilities.

Model results indicate that nonpoint sources related to agricultural land uses have the greatest impact on the fecal coliform bacteria loading in the Altamaha River basin. Direct inputs of fecal coliform bacteria from "other sources" (i.e., animal access to streams, illicit discharges of fecal coliform bacteria and failing septic systems) are also shown to increase bacteria loading in the watershed. Reductions in these loading rates reduce the in-stream fecal coliform bacteria levels. Nonpoint source loading rates representing existing conditions during the critical period are shown in Table 6.

8.3 Margin of Safety (MOS)

There are two methods for incorporating a MOS in the analysis: a) implicitly incorporate the MOS using conservative model assumptions to develop allocations; or b) explicitly specify a portion of the TMDL as the MOS and use the remainder for allocations. Both an explicit and an implicit MOS were incorporated in these TMDLs. Implicit MOS include conservative modeling assumptions and a continuous simulation that incorporates a range of meteorological events. Conservative modeling assumptions used include: septic systems discharging directly into the streams, conservative estimates of instream decay, and all land areas considered to be connected directly to streams. An explicit MOS was included in the TMDLs by reducing the load allocation by 10 percent.

8.4 Determination of TMDL, WLA, and LA

The TMDL is the total amount of pollutant that can be assimilated by a water body while maintaining water quality standards. Fecal coliform bacteria TMDLs are expressed as counts per 30-day period as the water quality standard is expressed in terms of the 30-day geometric mean. The TMDL, therefore, represents the maximum fecal coliform bacteria load that can be assimilated by a stream during the critical 30-day period while maintaining the fecal coliform bacteria water quality standard of 200 counts / 100 ml. As previously stated, the TMDL is calculated using the equation:

$$\text{TMDL} = \Sigma\ \text{WLAs} + \Sigma\ \text{LAs} + \text{MOS}$$

With MOS equal to10 percent of the LA value, the TMDL, ∑WLA, and ∑LA were determined according to the following procedure:

- The calibrated model, corresponding to the portion of the watershed that is upstream of the pour point of the listed waterbody segment was run for a time period that included the critical condition as specified in Table 6.

- The WLA component is zero on both Doctors Creek and Goose Creek.

- Fecal coliform land loading variables and the magnitude of loading from sources modeled as “other direct sources” were adjusted within a reasonable range of known values until the resulting fecal coliform concentration at the pour point of the listed water body segment was less than or equal to 200 counts/100ml.

- The ∑LA is the daily fecal coliform load indirectly going to surface waters from all modeled land use areas as a result of buildup/washoff processes plus the daily discharge load sources modeled as “other direct sources” and the result summed over the 30-day critical period. The resultant load was reduced by 10 percent and represents the MOS.

The TMDL components for the listed water bodies are summarized in Table 7.

8.4.1 Waste Load Allocations

There are no NPDES permitted facilities that discharge fecal coliform bacteria in either Doctors Creek or Goose Creek. Future facility permits will require end-of-pipe limits equivalent to the water quality standard of 200-counts/100 ml.

8.4.2 Load Allocations

There are two modes of transport for nonpoint source fecal coliform bacteria loading in the model. First, loading from failing septic systems, and animals in the stream are modeled as “other direct sources” to the stream and are independent of precipitation. The second mode involves loading resulting from fecal coliform accumulation on land surfaces and wash-off during storm events. Fecal coliform applied to land is subject to a die-off rate and an absorption rate before it is transported to the stream.

Model results were analyzed to determine which sources of fecal coliform have the greatest impact on the fecal coliform bacteria loadings in the watersheds of Doctors Creek and Goose Creek. In general, nonpoint source runoff contributes the greatest fecal coliform load to the streams. Reductions in both urban and agricultural loads to the stream as well as reductions in direct sources to the stream (i.e., animal access to streams and leaking septic systems) are shown to improve water quality conditions. The percent reductions required from nonpoint source loads to the impaired streams are shown in Table 8.

Best management practices (BMPs) that could be used to implement this TMDL include controlling pollution from agriculture and urban runoff, identification and elimination of illicit discharges and other unknown “direct sources” of fecal coliform bacteria to the streams, and repair of failing septic systems. Loading from agricultural sources may be minimized by adoption of NRCS resource management practices. NRCS practices include measures such as covering manure stacks exposed to the environment; reducing animal access to streams; and applying manure to agricultural lands at agronomic rates. Measures, which can reduce urban contributions, include encouragement of households and businesses to connect to public sewer systems and reduce the population using septic systems.

8.4.3 Seasonal Variation

Seasonal variation was incorporated in the continuous simulation water quality model by using varying monthly loading rates, daily meteorological data, and a ten-year time period.

9.0 RECOMMENDATIONS

The TMDL analysis was performed using the best data available to specify WLAs and LAs that will meet the water quality criteria for fecal coliform in the Altamaha River basin so as to support the use classification specified for each of the listed segments in Table 2. The following recommendations and strategies are targeted toward source identification, collection of data to support additional modeling and evaluation, and subsequent reduction in sources that are causing impairment of water quality.

9.1 Point Source Facilities

All future discharges from point source facilities will be required to be in compliance with the conditions of their NPDES permit at all times. All permitted facilities with the potential to discharge fecal coliform which do not currently have a fecal coliform limit will be given a fecal coliform limit of not more than 200 counts / 100 ml during the permit reissuance process.

9.2 Urban Sources of Fecal Coliform Loading

Urban sources of fecal coliform can best be addressed using a strategy which involves public participation and intergovernmental coordination to reduce the discharge of pollutants to the maximum extent practicable using management practices, control techniques, public education, and other appropriate methods and provisions. Monitoring programs conducted by cities, counties, and state agencies to identify the types and extent of fecal coliform water quality problems, relative degradation or improvement over time, areas of concern, and source identification are recommended.

9.3 Agricultural Sources of Fecal Coliform Loading

The Georgia Environmental Protection Division (EPD) should coordinate with the Georgia Soil and Water Conservation Commission, and the Natural Resources Conservation Service (NRCS) to address issues concerning fecal coliform loading from agricultural lands in the Altamaha River basin. It is recommended that information (such as livestock populations by subwatershed, animal access to streams, manure application practices, etc.) be evaluated periodically so that watershed models can be updated to reflect current conditions. It is further recommended that BMPs be utilized to reduce the amount of fecal coliform bacteria transported to surface waters from agricultural sources to the maximum extent practicable.

9.4 Stream Monitoring

Further monitoring of the fecal coliform concentrations at current and additional water quality monitoring stations in the watershed is needed to better characterize sources of fecal coliform bacteria and document future reduction of loading. Georgia's watershed management approach specifies a five-year cycle for planning and assessment. Watersheds will be examined (or re-examined) as appropriate, on a rotating basis.

9.5 Future Efforts

This TMDL represents the first phase of a long-term process to reduce fecal coliform loading to meet water quality standards in the Altamaha River basin. Implementation strategies will be reviewed and the TMDLs will be refined as necessary in the next phase (next five-year cycle). The phased approach will support progress toward water quality standards attainment in the future. In accordance with USEPA TMDL guidance, these TMDLs may be revised based on results of future monitoring and source characterization data efforts.

10.0 Public Participation

A sixty-day public comment period will be provided for this TMDL document. During the public comment period, the availability of the TMDLs will be public noticed, the TMDLs will be posted on EPA's website, a copy of the TMDLs will be provided as requested, and the public will be invited to provide comments on the TMDLs.

11.0 Implementation

EPA has always recognized that implementation of TMDLs is important, since a TMDL improves water quality when the pollutant allocations are implemented, not when a TMDL is established. EPA believes, however, that TMDL implementation and implementation planning is the responsibility of the State of Georgia, through its administration of the National Pollutant Discharge Elimination System (NPDES) point source permit program and through its administration of any regulatory or non-regulatory nonpoint source control programs. Neither the Clean Water Act nor EPA's current regulations require a TMDL to include an implementation plan.

A consent decree in the case of Sierra Club v. EPA, 1:94-cv-2501-MHS (N.D. Ga.) requires the State or EPA to develop TMDLs for all waterbodies on the State of Georgia's current 303(d) list according to a schedule contained in the decree. On July 24, 2001, the district court entered an order finding that the decree also requires EPA to develop TMDL implementation plans. EPA disagrees with the court's conclusion that implementation plans are required by the decree and has appealed the July 24, 2001 order.

The Agency is moving forward, however, to comply with the obligations contained in the order. Since EPA does not believe it is possible to propose an adequate plan in the time available between July 24, 2001 and the proposal of this TMDL, this proposal outlines the steps EPA intends to undertake to develop an implementation plan before the TMDL is established.

Between now and the time this TMDL is established, EPA intends to coordinate with the Georgia Environmental Protection Division to prepare an implementation plan for this TMDL. EPA will work with the Georgia Environmental Protection Division to facilitate stakeholder involvement in this process, including members of the public and appropriate units of local, state, and federal government. EPA will make its best efforts to afford the public an opportunity to provide comments about an implementation plan before it is finalized. If the July 24, 2001 Order is vacated, EPA would expect to support efforts by the State of Georgia to develop an implementation plan for this TMDL.

Table 1 Land Use Distribution for the Altamaha River Basin (Source: MRLC, 1993)

Stream/Segment	Land Use Categories - in units of acres (percent)																
	Bare Rock/Sand/Clay	Deciduous Forest	Emergent Herbaceous Wetlands	Evergreen Forest	High Intensity Commercial/Industrial/Transportation	Low Intensity Commercial/Industrial/Transportation	High Intensity Residential	Low Intensity Residential	Mixed Forest	Open Water	Other Grasses Urban/Recreational	Pasture/Hay	Quarries/Strip Mines/Gravel Pits	Row Crops	Transitional	Woody Wetlands	Unclassified
Doctors Creek (Upstream of Jones Creek)	13 (0.0)	1444 (3.3)	87 (0.2)	21267 (49.0)	4 (0.0)	0 (0.0)	6 (0.0)	96 (0.2)	3353 (7.7)	28 (0.1)	1 (0.0)	954 (2.2)	14 (0.0)	3127 (7.2)	4820 (11.1)	8195 (18.9)	0 (0.0)
Goose Creek (U/S Rd. S1922 to Little Goose Creek)	35 (0.1)	3100 (6.2)	17 (0.0)	18338 (36.8)	86 (0.2)	0 (0.0)	16 (0.0)	322 (0.6)	4773 (9.6)	343 (0.7)	35 (0.1)	1711 (3.4)	105 (0.2)	15299 (30.7)	3545 (7.1)	2149 (4.3)	0 (0.0)

Table 2 Waterbodies Listed for Fecal Coliform Bacteria in the Altamaha River Basin (Source: EPD)

Stream Name	**Segment Description**	Segment Length (miles)	Designated Use Classification	Partially Supporting Designated Uses	Not Supporting Designated Uses
Doctors Creek	Upstream of Jones Creek	5	Fishing		**X**
Goose Creek	U/S Rd. S1922 to Little Goose Creek	8	Fishing	**X**	

Table 3 1999 Water Quality Monitoring Stations (Source: EPD)

Stream Name	**Segment Description**	USGS Monitoring Station No.	Monitoring Station Description
Doctors Creek	Upstream of Jones Creek	02226060	Doctors Creek at State Road 99 near Ludowici, Georgia
Goose Creek	U/S Rd. S1922 to Little Goose Creek	02225980	Goose Creek at Woods Road (County Road 30) near Jesup, Georgia

Table 4 Water Quality Monitoring Data (Source: EPD)

Stream/Segment	Sample Dates	Fecal Coliform Bacteria (MPN/100 ml.)	Geometric Mean (#/100 ml.)	Sample Dates	Fecal Coliform Bacteria (MPN/100 ml.)	Geometric Mean (#/100 ml.)	Sample Dates	Fecal Coliform Bacteria (MPN/100 ml.)	Geometric Mean (#/100 ml.)	Sample Dates	Fecal Coliform Bacteria (MPN/100 ml.)	Geometric Mean (#/100 ml.)
Doctors Creek (Upstream of Jones Creek)	01/20/1999 02/02/1999 02/09/1999 02/17/1999	50 330 80 110	110	03/23/1999 04/13/1999 04/21/1999 04/22/1999	<20 20 150 50	42	06/23/1999 06/30/1999 07/14/1999 04/21/1999	490 790 90 <20	162	09/22/1999 09/29/1999 10/06/1999 10/20/1999	490 1100 120 50	238
Goose Creek (U/S Rd. S1922 to Little Goose Creek)	03/30/1999 04/12/1999 04/19/1999 04/27/1999	220 20 70 700	121	05/17/1999 05/24/1999 06/07/1999 06/14/1999	120 40 <20 330	75	07/26/1999 08/09/1999 08/16/1999 08/23/1999	110 490 270 490	291	11/15/1999 11/29/1999 12/06/1999 12/13/1999	1300 110 <20 200	155

Table 5 NPDES Facilities Discharging Fecal Coliform in the Altamaha River Basin

Facility Name	NPDES Permit No.	1999 Discharge Monitoring Reports		NPDES Permit Limits	
		Avg. Flow (MGD)	Avg. Fecal Coliform Loading[a] (counts/hr)	Avg. Flow (MGD)	Avg. Fecal Coliform Loading[b] (counts/hr)
DOC-Rogers Correctional Institute	GA0022900	0.64	4.39X10^07	0.85	2.69X10^08
Georgia Power Hatch	GA0004120	No data available		43.4	1.37X10^10
Glenville WPCP	GA0031836	No data available		0.88	2.78X10^08
Jessup WPCP	GA0026000	No data available		2.50	7.90X10^08
Lyons Pond #1	GA0033405	0.36	2.10X10^07	0.67	2.12X10^08
Lyons North WPCP #2	GA0033391	No data available		0.67	2.12X10^08
Rayonier Inc., Jessup	GA0003620	No data available		67.00	2.12X10^10
Santa Claus Pond	GA0050059	No data available		0.01	3.16X10^06
Tennille Pond	GA0049956	No data available		0.45	1.42X10^08
Vidalia WPCP	GA0025488	0.64	3.79X10^06	1.88	5.94X10^08
Wrightsville Pond	GA0032395	No data available		0.745	2.35X10^08

a Loadings based on CY 1999 average fecal coliform concentration and mean flow reported on DMRs.
b Loadings based on Monthly Average fecal coliform permit limit at monthly average permitted flow (design flow used for facilities without a permitted monthly flow limit). A fecal coliform loading of 200 counts/100 mL was assumed for facilities without a fecal coliform bacteria permit limit.

Table 6 Livestock Distribution By County In The Altamaha River Basin (Source: USDA, 1977)

County	Livestock						
	Beef Cow	Milk Cow	Cattle	Chicken Layers	Chickens - Broilers Sold	Hogs	Sheep
Long	732	0	1377	0	2245000	30	0
Wayne	2312	476	4831	0	273	3400	330

Table 7 Fecal Coliform Loading Rates for Existing Conditions During Critical Period

Stream/Segment	**Critical Conditions Period**	**Loading from NPDES Discharges** (counts/30 days)	**Loading from Surface Runoff and Other Direct Sources** (counts/30 days)
Doctors Creek - (Upstream of Jones Creek)	9/9/90 – 10/8/90	0	1.25×10^{12}
Goose Creek - (U/S Rd. S1922 to Little Goose Creek)	6/13/90 – 7/12/90	0	5.31×10^{11}

Table 8 TMDL Components

Stream/Segment	**WLAs** (counts/30 days)	LAs (counts/30 days)	Margin of Safety	TMDL (counts/30 days)	Percent Reduction
Doctors Creek - (Upstream of Jones Creek)	0	1.87×10^{11}	2.07×10^{10}	1.87×10^{11}	83
Goose Creek - (U/S Rd. S1922 to Little Goose Creek)	0	1.45×10^{11}	1.61×10^{10}	1.45×10^{11}	70

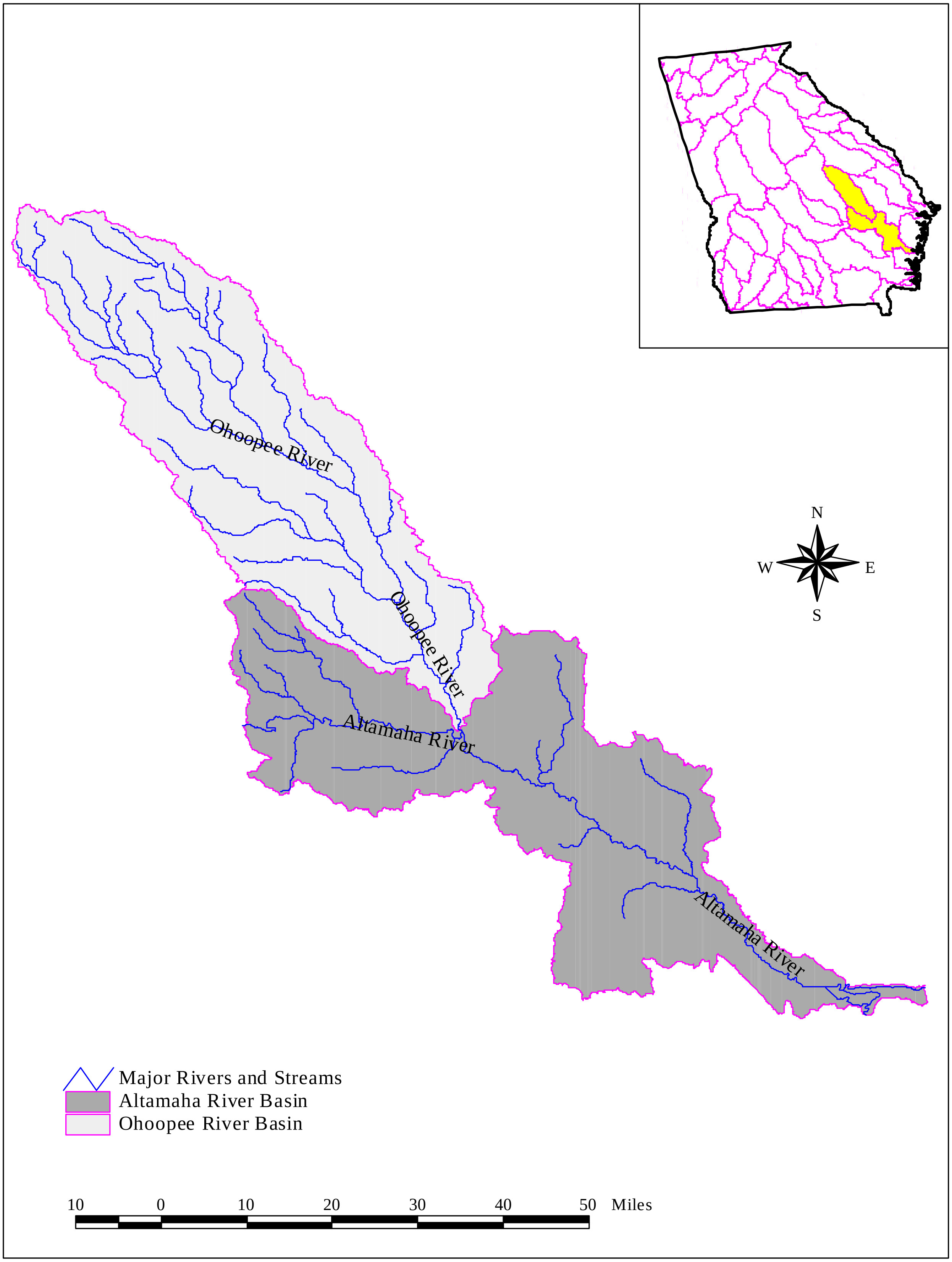


Figure 1. Altamaha and Ohoopee River Basins.

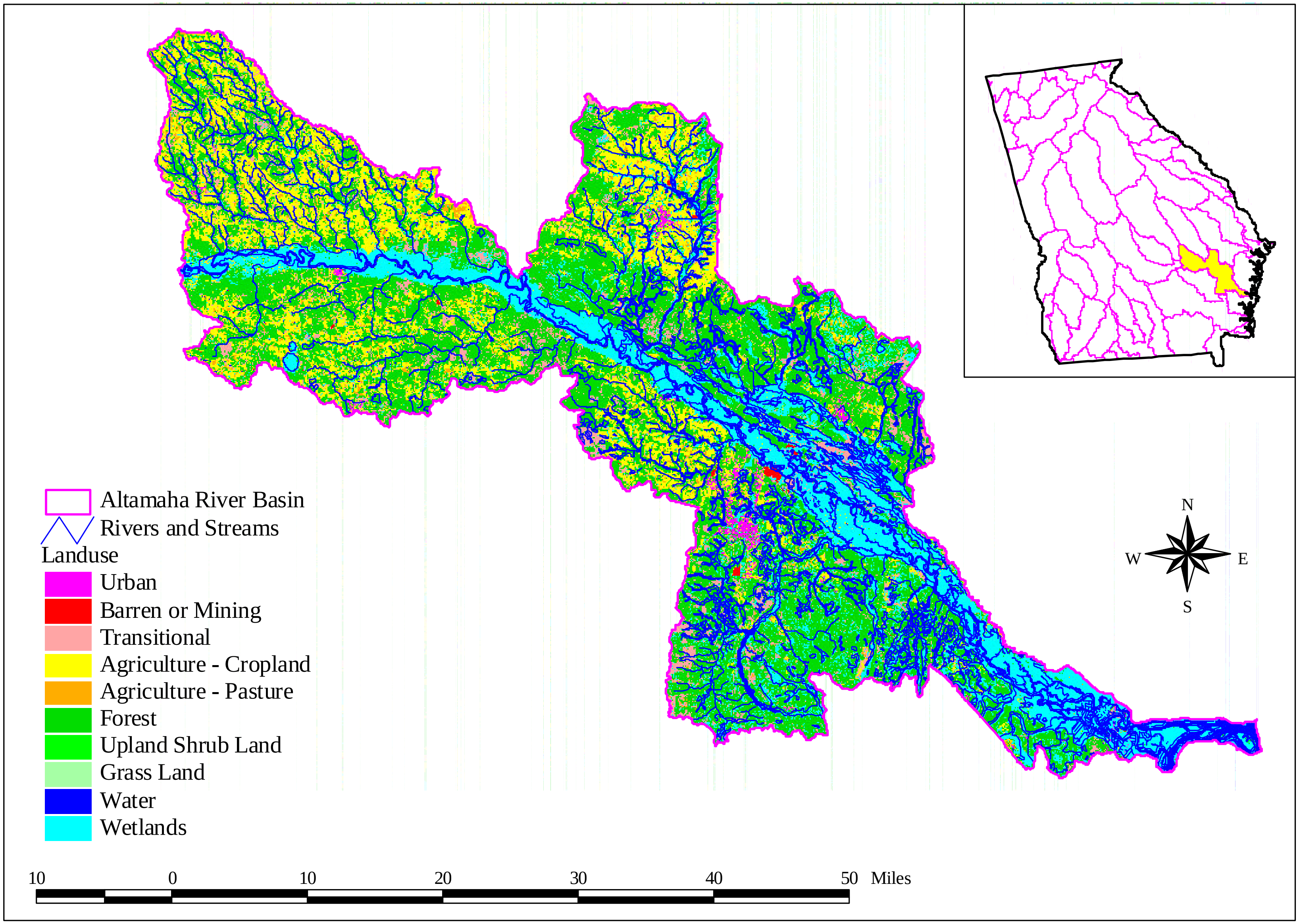


Figure 2. Landuse Distribution, Altamaha River Basin.

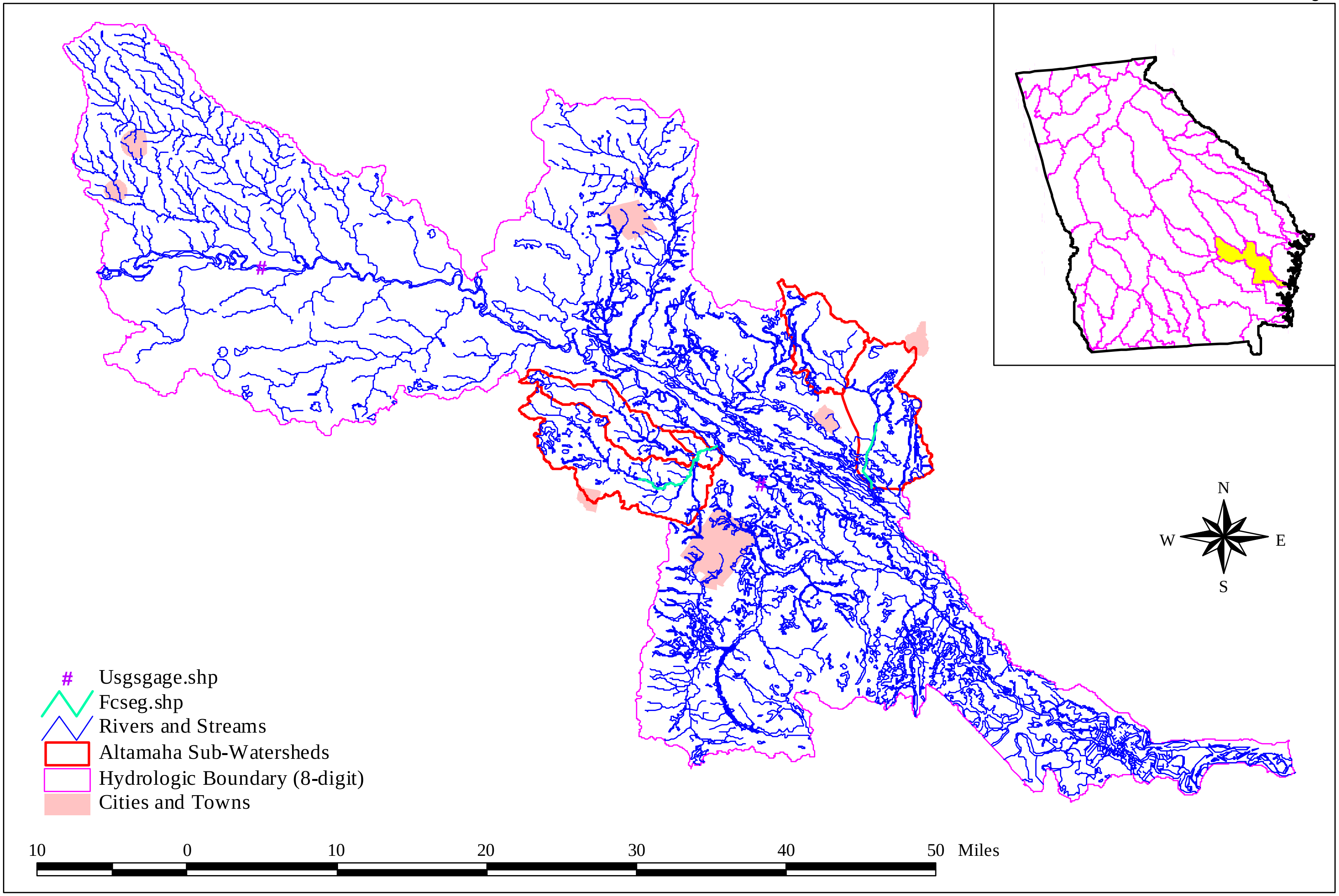


Figure 3. Sub-Watersheds and 303(d) Listed Streams, Altamaha River Basin.

REFERENCES

American Society of Agricultural Engineers (ASAE), 1998. ASAE Standards, 45th Edition, Standards Engineering Practices Data.

Horner. *Water Quality Criteria/Pollutant Loading Estimation/Treatment Effectiveness Estimation*. In R.W. Beck and Associates, Covington Master Drainage Plan, King County Surface Water Management Division, Seattle, Washington, 1992.

North Carolina State Unviersity (NCSU), 1994. *Livestock Manure Production and Characterization in North Carolina*, North Carolina Cooperative Extension Service, North Carolina State University College of Agriculture and Life Sciences, Raleigh, January 1994.

Georgia EPD, 2000. *Final Georgia 2000 §303(d) / §305(b) List, August 2000 (As Revised April, 2001).* State of Georgia, Department of Natural Resources, Environmental Protection Division, Water Protection Branch.

Georgia EPD, 2000. *State of Georgia Rules and Regulations for Water Quality Control, Chapter 391-3-6 Revised, July, 2000.* State of Georgia, Department of Natural Resources, Environmental Protection Division, Water Protection Branch.

Georgia WRD, 1999. Personal Communications with a representative from the Wildlife Resources Division – Georgia Department of Natural Resources, 2070 U.S. Highway 278, SE, Social Circle, GA. November, 1999.

Lombardo, P.S., 1972. *Mathematical Model of Water Quality in Rivers and Impoundments,*Technical Report, Hydrocomp, Inc.

USDA, 1977. *1997 Census of Agriculture, Volume 1, Geographic Area Series, Part 42,*U.S. Department of Agriculture, National Agricultural Statistics Service. AC97-A-42, March 1999.

USDA, 2001. Personal Communications with Mr. Jimmy Bramblett, Water Resources Specialist, U.S. Department of Agriculture – NRCS, 355 East Hancock Ave., Athens, GA. March-May, 2001.

USEPA, 1991. *Guidance for Water Quality–based Decisions: The TMDL Process.* U.S. Environmental Protection Agency, Office of Water, Washington, DC. EPA-440/4-91-001, April 1991.

USEPA, 2001. *Protocol for Developing Pathogen TMDLs, First Edition.* U.S. Environmental Protection Agency, Office of Water, Washington, DC. EPA-841-R-00-002, January, 2001.

USEPA. 2000. *Draft Level III and IV Ecoregions of EPA Region IV*. U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, Corvallis, Oregon.

USEPA, 1998. *Better Assessment Science Integrating Point and Nonpoint Sources (BASINS), Version 2.0 User's Manual*, U.S. Environmental Protection Agency, Office of Water, Washington D.C.

APPENDIX A:

HYDROLOGY CALIBRATIONS

Table A1 - Calibration and Validation Stations for Hydrological Parameters Below the GA Fall Line (Coastal Plain).

Station Number	Station Name	Type	Drainage Area (acres)	Reference WDM station
02225500	Ohoopee River near Reidsville, GA	Calibration	735216	Dublin
02215500	Ocmulgee River at Lumber City, GA	Validation	3366386	Abbeville
02223500	Oconee River at Dublin, GA	Validation	2804097	Milledgeville
02225000	Altamaha River near Baxley, GA	Validation	7414025	Hazlehurst
02226000	Altamaha River at Doctortown, GA	Validation	8738182	Jesup

Figure A.1. Location of Hydrology Calibration and Validation Stations

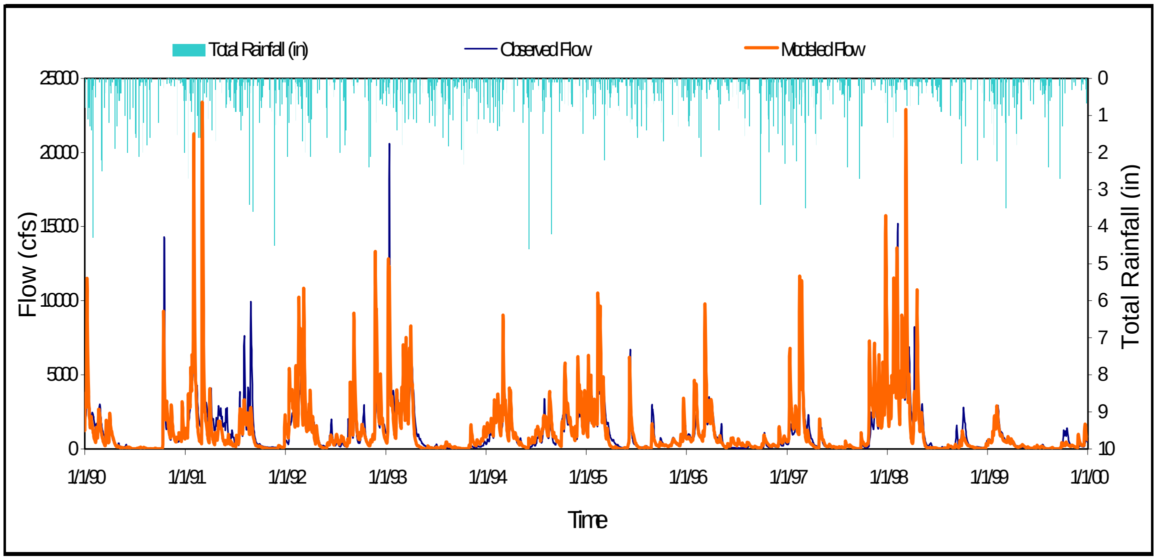


Figure A.2. 10-Year Calibration (Daily Flow) at 02225500 – Ohoopee River near Reidsville, GA.

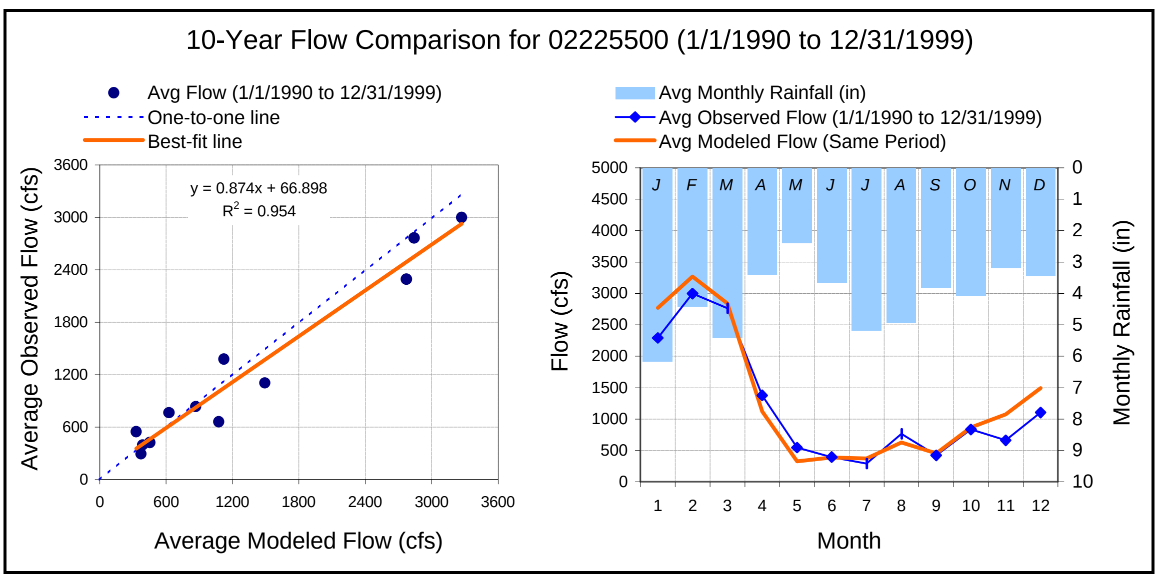


Figure A.3. 10-Year Calibration (Monthly Average) at 02225500 – Ohoopee River near Reidsville, GA.

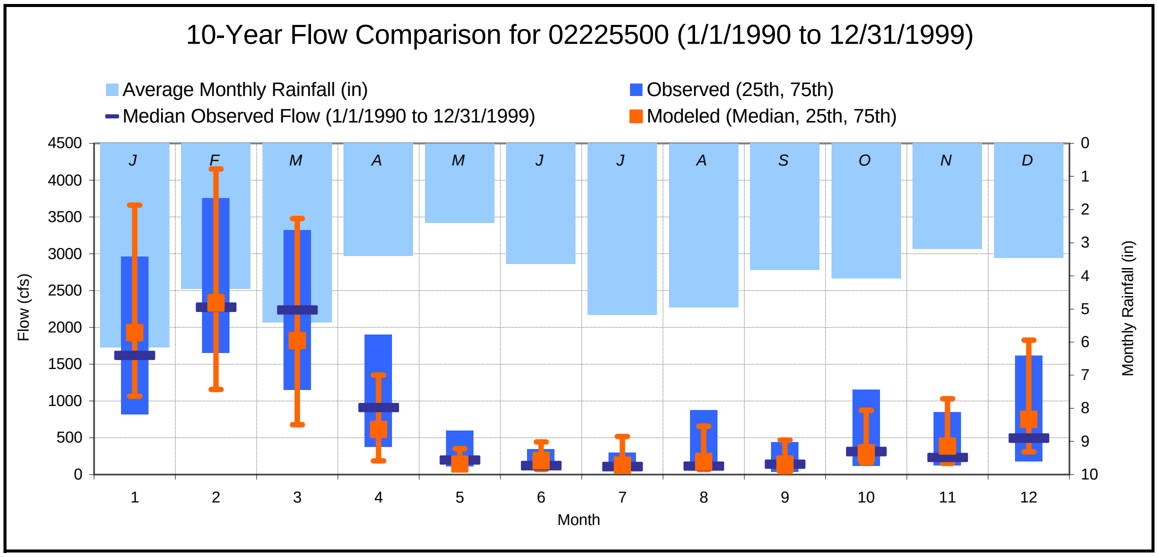
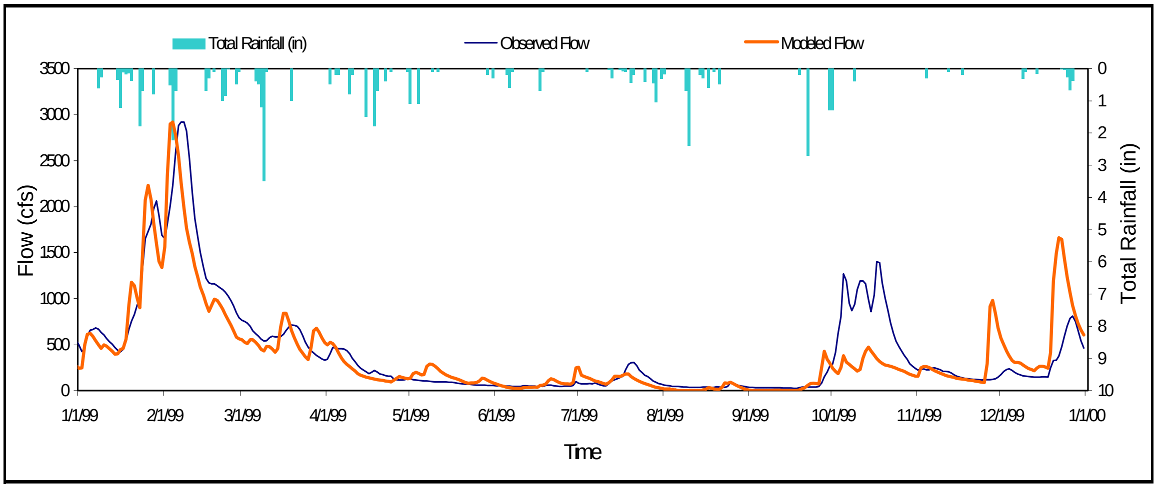


Figure A.4. 10-Year Calibration (Monthly Medians) at 02225500 – Ohoopee River near Reidsville, GA.

Simulation Name:	02225500	**Simulation Period:**	
		Watershed Area (ac):	730428.00
Period for Flow Analysis			
Begin Date:	**01/01/90**	**Baseflow PERCENTILE:**	2.5
End Date:	**12/31/99**	*Usually 1%-5%*	
Total Simulated In-stream Flow:	**153.74**	Total Observed In-stream Flow:	**142.28**
Total of highest 10% flows:	**76.16**	Total of Observed highest 10% flows:	**63.14**
Total of lowest 50% flows:	**9.69**	Total of Observed Lowest 50% flows:	**9.59**
Simulated Summer Flow Volume (months 7-9):	**14.54**	Observed Summer Flow Volume (7-9):	**14.79**
Simulated Fall Flow Volume (months 10-12):	**34.37**	Observed Fall Flow Volume (10-12):	**26.02**
Simulated Winter Flow Volume (months 1-3):	**86.76**	Observed Winter Flow Volume (1-3):	**78.63**
Simulated Spring Flow Volume (months 4-6):	**18.07**	Observed Spring Flow Volume (4-6):	**22.84**
Total Simulated Storm Volume:	**153.40**	Total Observed Storm Volume:	**138.34**
Simulated Summer Storm Volume (7-9):	**14.46**	Observed Summer Storm Volume (7-9):	**13.80**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**7.45**	10	
Error in 50% lowest flows:	**1.04**	10	
Error in 10% highest flows:	**17.10**	15	
Seasonal volume error - Summer:	**-1.72**	30	
Seasonal volume error - Fall:	**24.29**	30	
Seasonal volume error - Winter:	**9.36**	30	
Seasonal volume error - Spring:	**-26.38**	30	
Error in storm volumes:	**9.81**	20	
Error in summer storm volumes:	**4.52**	50	

Figure A.5. 10-Year Calibration Statistics at 02225500 – Ohoopee River near Reidsville, GA.

Figure A.6. Calendar Year 1999 (Daily Flow) at 02225500 – Ohoopee River near Reidsville, GA.



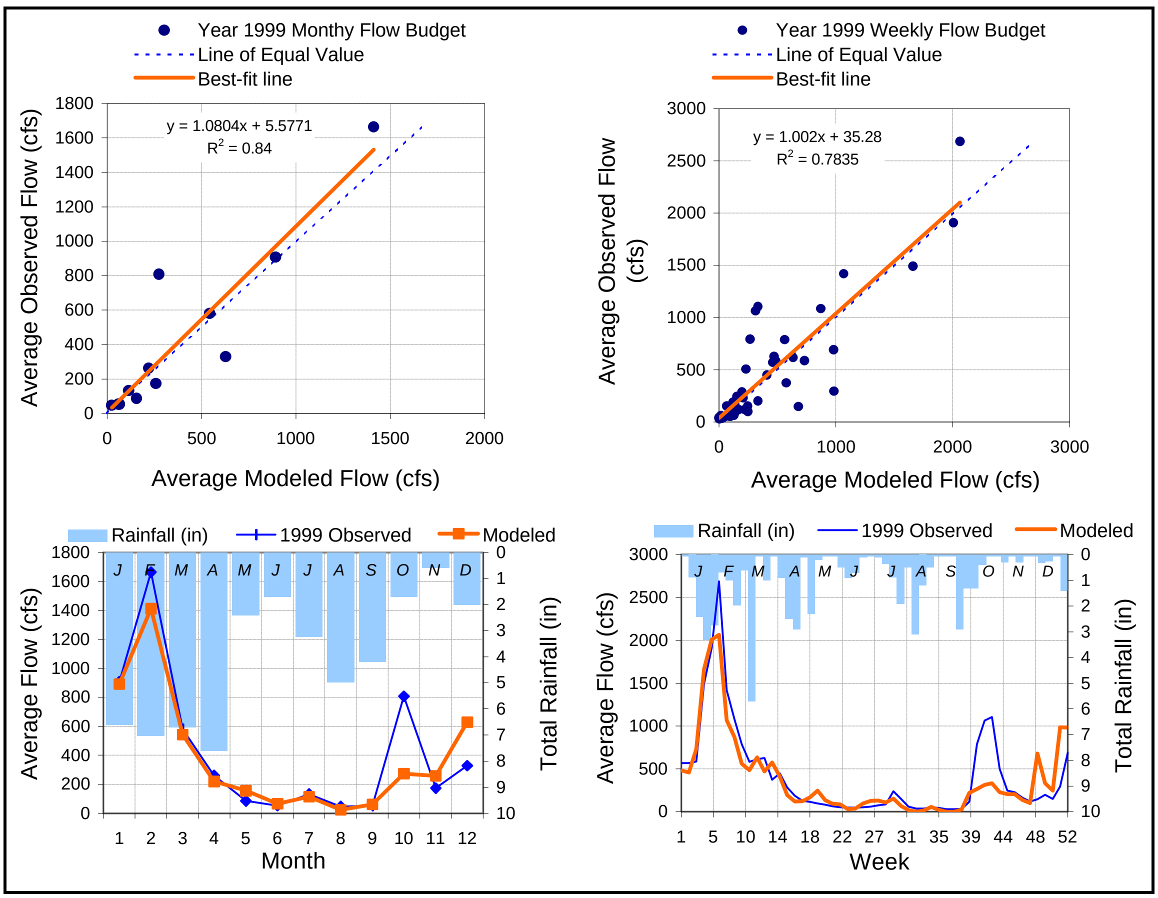


Figure A.7. Calendar Year 1999 (Monthly and Weekly) at 02225500 – Ohoopee River near Reidsville, GA.

Simulation Name:	02225500	**Simulation Period:**	
		Watershed Area (ac):	730428.00
Selected a Year for Flow Analysis:	**1999**		
Type of Year (1=Calendar, 2=Water Year)	**1**	**Baseflow PERCENTILE:**	2.5
Calendar Year 1999:		*Usually 1%-5%*	
1/1/1999 to 12/31/1999			
Total Simulated In-stream Flow:	**4.54**	Total Observed In-stream Flow:	**4.96**
Total of highest 10% flows:	**1.95**	Total of Observed highest 10% flows:	**2.08**
Total of lowest 50% flows:	**0.50**	Total of Observed Lowest 50% flows:	**0.47**
Simulated Summer Flow Volume (months 7-9):	**0.20**	Observed Summer Flow Volume (7-9):	**0.23**
Simulated Fall Flow Volume (months 10-12):	**1.17**	Observed Fall Flow Volume (10-12):	**1.32**
Simulated Winter Flow Volume (months 1-3):	**2.74**	Observed Winter Flow Volume (1-3):	**3.02**
Simulated Spring Flow Volume (months 4-6):	**0.44**	Observed Spring Flow Volume (4-6):	**0.39**
Total Simulated Storm Volume:	**4.52**	Total Observed Storm Volume:	**4.60**
Simulated Summer Storm Volume (7-9):	**0.20**	Observed Summer Storm Volume (7-9):	**0.14**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**-9.32**	10	
Error in 50% lowest flows:	**5.09**	10	
Error in 10% highest flows:	**-6.78**	15	
Seasonal volume error - Summer:	**-16.27**	30	
Seasonal volume error - Fall:	**-13.02**	30	
Seasonal volume error - Winter:	**-10.35**	30	
Seasonal volume error - Spring:	**10.12**	30	
Error in storm volumes:	**-1.56**	20	
Error in summer storm volumes:	**28.69**	50	

Figure A.8. Calendar Year 1999 Statistics at 02225500 – Ohoopee River near Reidsville, GA.

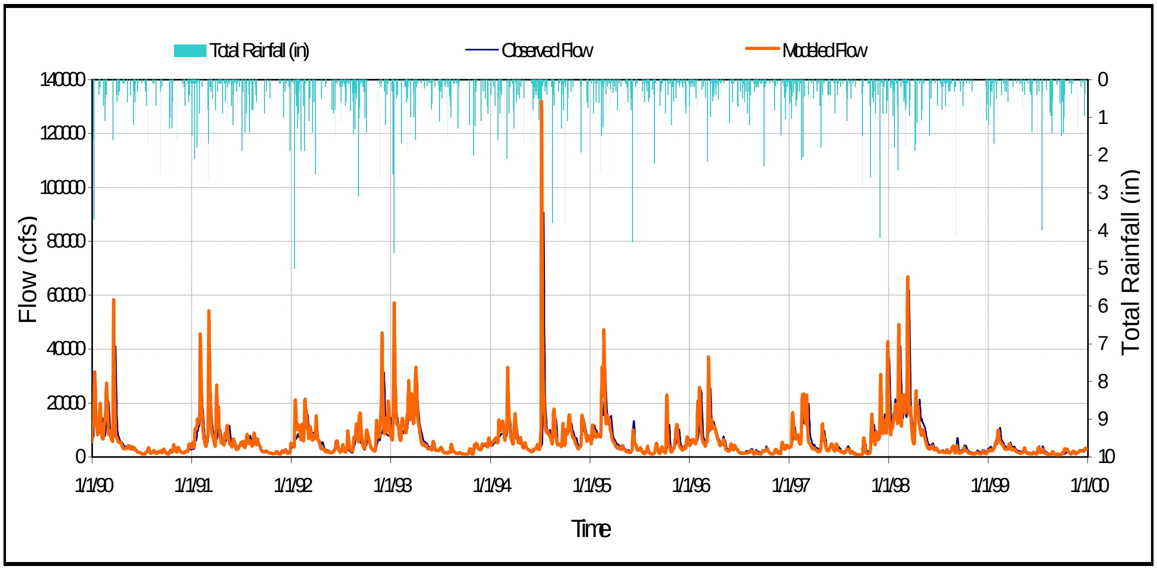


Figure A.9. 10-Year Validation (Daily Flow) at 02215500 – Ocmulgee River at Lumber City, GA.

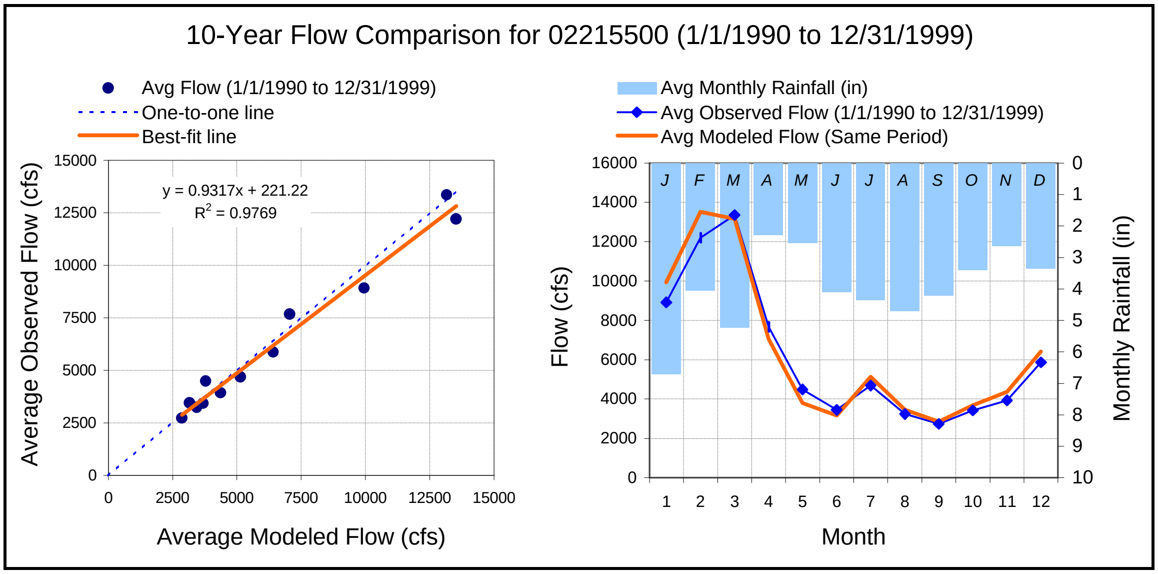


Figure A.10. 10-Year Validation (Monthly Average) at 02215500 – Ocmulgee River at Lumber City, GA.

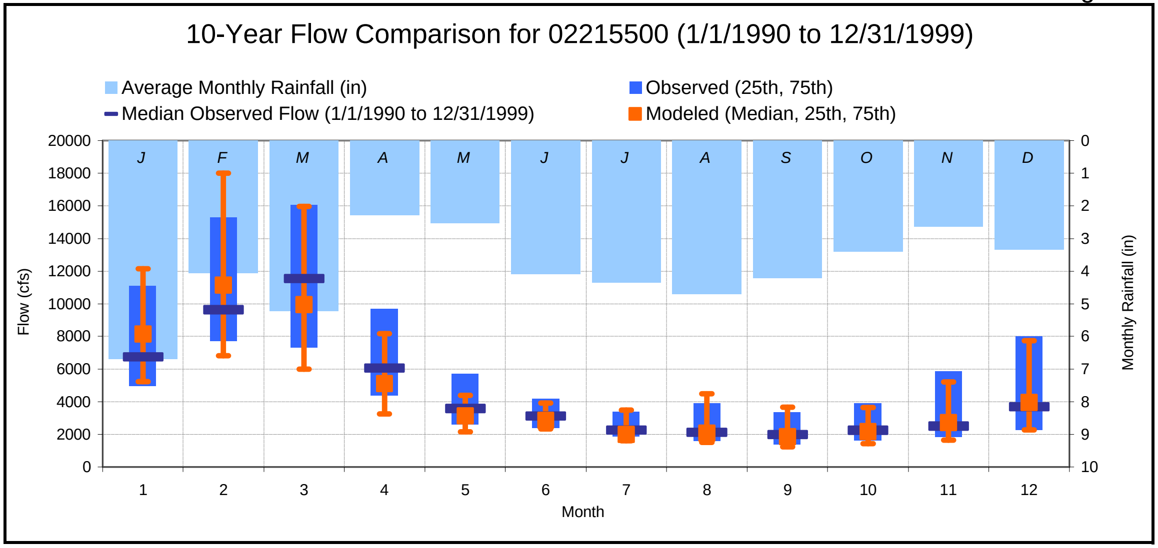


Figure A.11. 10-Year Validation (Monthly Medians) at 02215500 – Ocmulgee River at Lumber City, GA.

Simulation Name:	02215500	**Simulation Period:**	
		Watershed Area (ac):	3366386
Period for Flow Analysis			
Begin Date:	**01/01/90**	**Baseflow PERCENTILE:**	2.5
End Date:	**12/31/99**	*Usually 1%-5%*	
Total Simulated In-stream Flow:	**163.87**	Total Observed In-stream Flow:	**158.47**
Total of highest 10% flows:	**61.83**	Total of Observed highest 10% flows:	**53.58**
Total of lowest 50% flows:	**27.34**	Total of Observed Lowest 50% flows:	**30.16**
Simulated Summer Flow Volume (months 7-9):	**24.86**	Observed Summer Flow Volume (7-9):	**23.16**
Simulated Fall Flow Volume (months 10-12):	**31.41**	Observed Fall Flow Volume (10-12):	**28.73**
Simulated Winter Flow Volume (months 1-3):	**77.60**	Observed Winter Flow Volume (1-3):	**73.13**
Simulated Spring Flow Volume (months 4-6):	**29.99**	Observed Spring Flow Volume (4-6):	**33.45**
Total Simulated Storm Volume:	**136.76**	Total Observed Storm Volume:	**126.78**
Simulated Summer Storm Volume (7-9):	**18.11**	Observed Summer Storm Volume (7-9):	**15.23**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**3.29**	10	
Error in 50% lowest flows:	**-10.33**	10	
Error in 10% highest flows:	**13.35**	15	
Seasonal volume error - Summer:	**6.84**	30	
Seasonal volume error - Fall:	**8.53**	30	
Seasonal volume error - Winter:	**5.76**	30	
Seasonal volume error - Spring:	**-11.51**	30	
Error in storm volumes:	**7.29**	20	
Error in summer storm volumes:	**15.93**	50	

Figure A.12. 10-Year Validation Statistics at 02215500 – Ocmulgee River at Lumber City, GA.

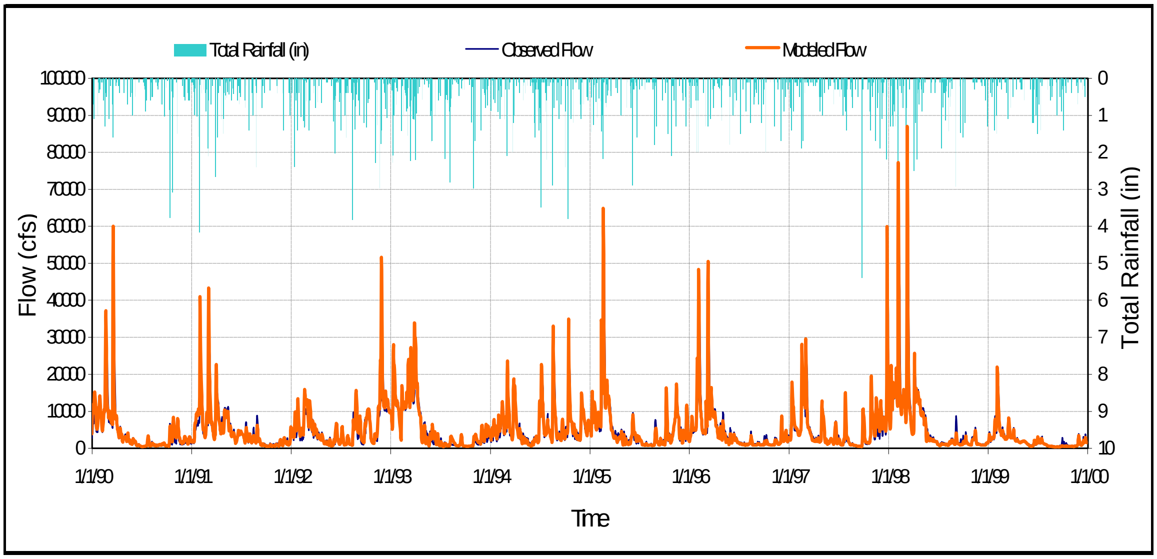


Figure A.13. 10-Year Validation (Daily Flow) at 02223500 – Oconee River at Dublin, GA.

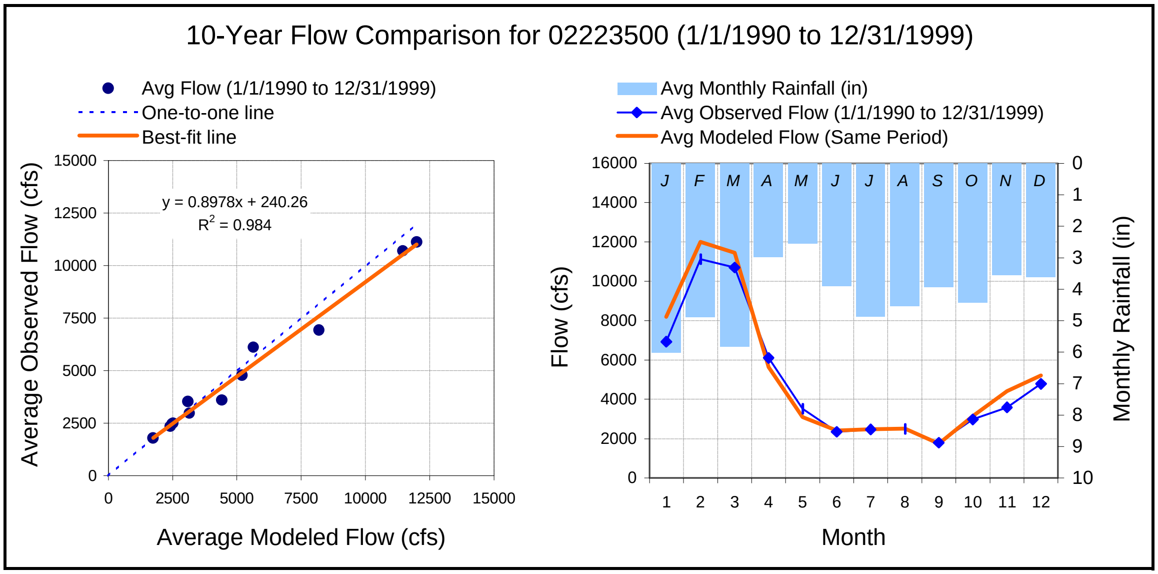


Figure A.14 10-Year Validation (Monthly Average) at 02223500 – Oconee River at Dublin, GA.

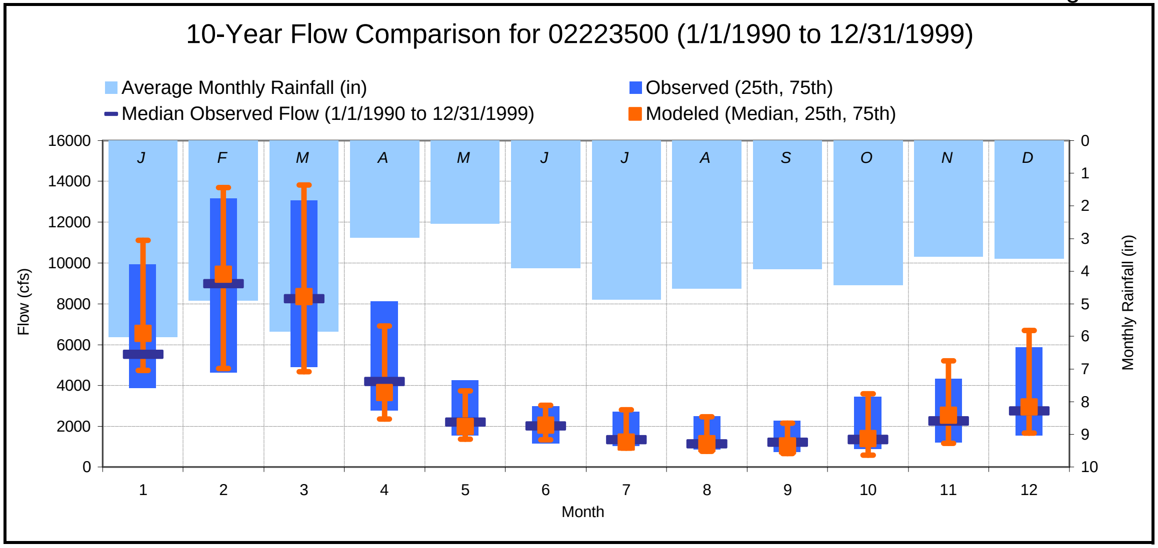


Figure A.15. 10-Year Validation (Monthly Medians) at 02223500 – Oconee River at Dublin, GA.

Simulation Name:	02223500	**Simulation Period:**	
		Watershed Area (ac):	2804097
Period for Flow Analysis			
Begin Date:	**01/01/90**	**Baseflow PERCENTILE:**	2.5
End Date:	**12/31/99**	*Usually 1%-5%*	
Total Simulated In-stream Flow:	**159.89**	Total Observed In-stream Flow:	**150.96**
Total of highest 10% flows:	**63.23**	Total of Observed highest 10% flows:	**56.09**
Total of lowest 50% flows:	**21.46**	Total of Observed Lowest 50% flows:	**22.45**
Simulated Summer Flow Volume (months 7-9):	**17.58**	Observed Summer Flow Volume (7-9):	**17.62**
Simulated Fall Flow Volume (months 10-12):	**33.23**	Observed Fall Flow Volume (10-12):	**29.53**
Simulated Winter Flow Volume (months 1-3):	**80.43**	Observed Winter Flow Volume (1-3):	**73.00**
Simulated Spring Flow Volume (months 4-6):	**28.64**	Observed Spring Flow Volume (4-6):	**30.81**
Total Simulated Storm Volume:	**145.27**	Total Observed Storm Volume:	**132.05**
Simulated Summer Storm Volume (7-9):	**13.93**	Observed Summer Storm Volume (7-9):	**12.90**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**5.59**	10	
Error in 50% lowest flows:	**-4.62**	10	
Error in 10% highest flows:	**11.30**	15	
Seasonal volume error - Summer:	**-0.22**	30	
Seasonal volume error - Fall:	**11.13**	30	
Seasonal volume error - Winter:	**9.24**	30	
Seasonal volume error - Spring:	**-7.55**	30	
Error in storm volumes:	**9.10**	20	
Error in summer storm volumes:	**7.39**	50	

Figure A.16. 10-Year Validation Statistics at 02223500 – Oconee River at Dublin, GA.

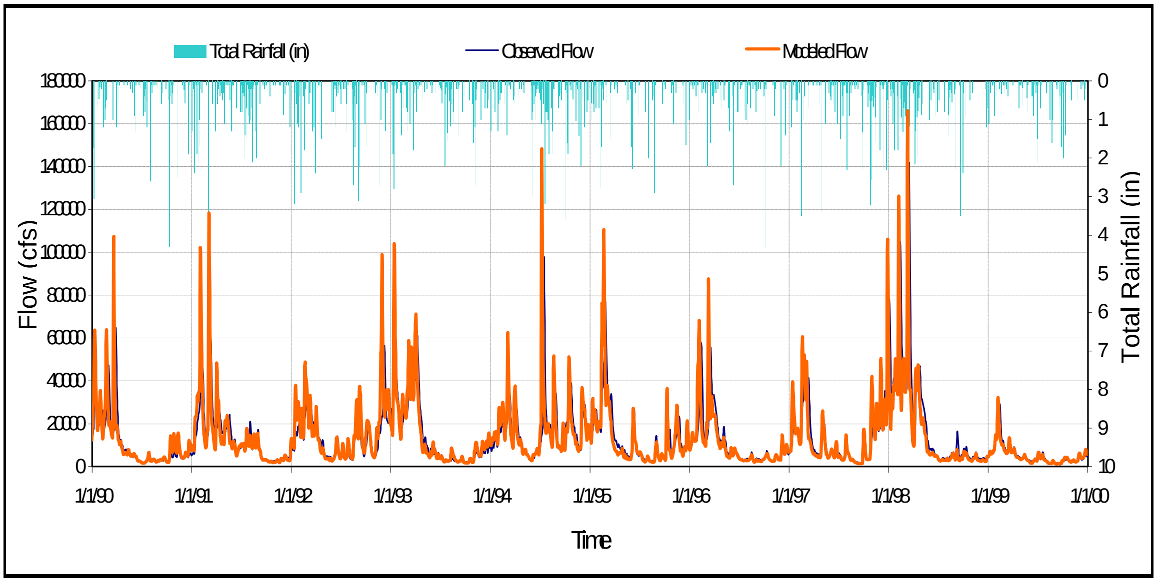


Figure A.17. 10-Year Validation (Daily Flow) at 02225000 – Altamaha River near Baxley, GA.

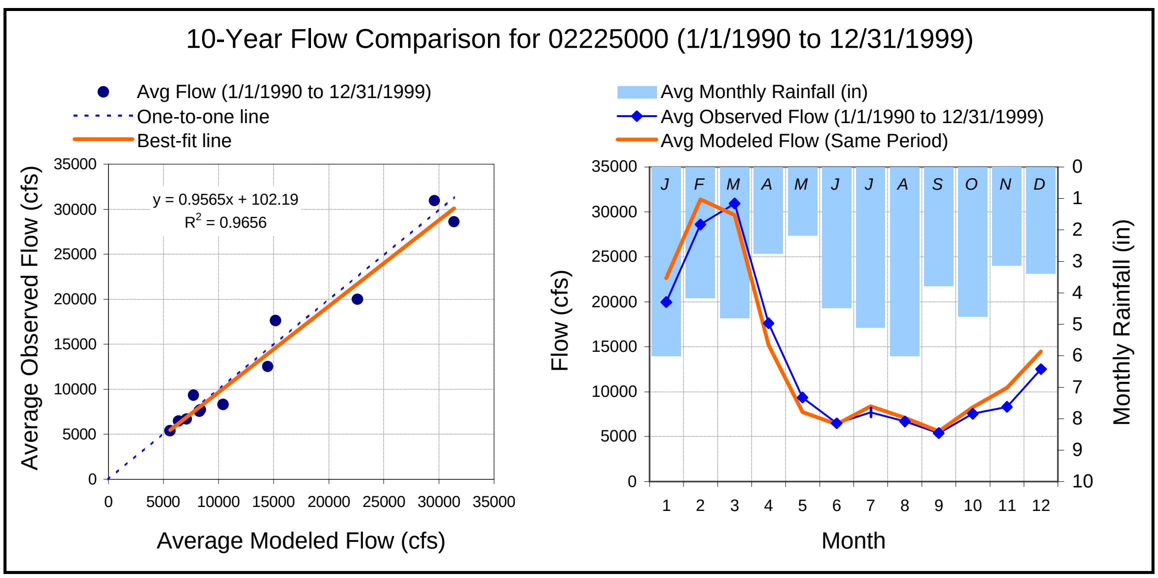


Figure A.18. 10-Year Validation (Monthly Average) at 02225000 – Altamaha River near Baxley, GA.

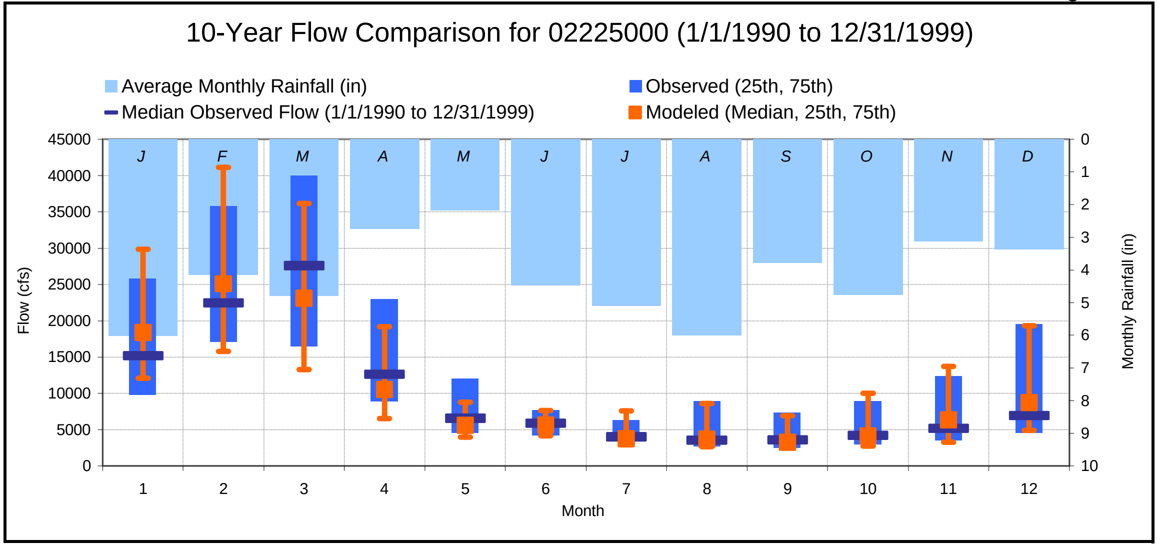


Figure A.19. 10-Year Validation (Monthly Medians) at 02225000 – Altamaha River near Baxley, GA.

Simulation Name:	02225000	**Simulation Period:**	
		Watershed Area (ac):	7414025
Period for Flow Analysis			
Begin Date:	**01/01/90**	**Baseflow PERCENTILE:**	2.5
End Date:	**12/31/99**	*Usually 1%-5%*	
Total Simulated In-stream Flow:	**162.30**	Total Observed In-stream Flow:	**156.52**
Total of highest 10% flows:	**61.54**	Total of Observed highest 10% flows:	**55.32**
Total of lowest 50% flows:	**24.30**	Total of Observed Lowest 50% flows:	**25.45**
Simulated Summer Flow Volume (months 7-9):	**20.78**	Observed Summer Flow Volume (7-9):	**19.53**
Simulated Fall Flow Volume (months 10-12):	**32.68**	Observed Fall Flow Volume (10-12):	**27.94**
Simulated Winter Flow Volume (months 1-3):	**80.39**	Observed Winter Flow Volume (1-3):	**76.56**
Simulated Spring Flow Volume (months 4-6):	**28.45**	Observed Spring Flow Volume (4-6):	**32.50**
Total Simulated Storm Volume:	**141.79**	Total Observed Storm Volume:	**132.50**
Simulated Summer Storm Volume (7-9):	**15.67**	Observed Summer Storm Volume (7-9):	**13.53**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**3.56**	10	
Error in 50% lowest flows:	**-4.72**	10	
Error in 10% highest flows:	**10.10**	15	
Seasonal volume error - Summer:	**6.06**	30	
Seasonal volume error - Fall:	**14.50**	30	
Seasonal volume error - Winter:	**4.77**	30	
Seasonal volume error - Spring:	**-14.24**	30	
Error in storm volumes:	**6.56**	20	
Error in summer storm volumes:	**13.68**	50	

Figure A.20. 10-Year Validation Statistics at 02225000 – Altamaha River near Baxley, GA.

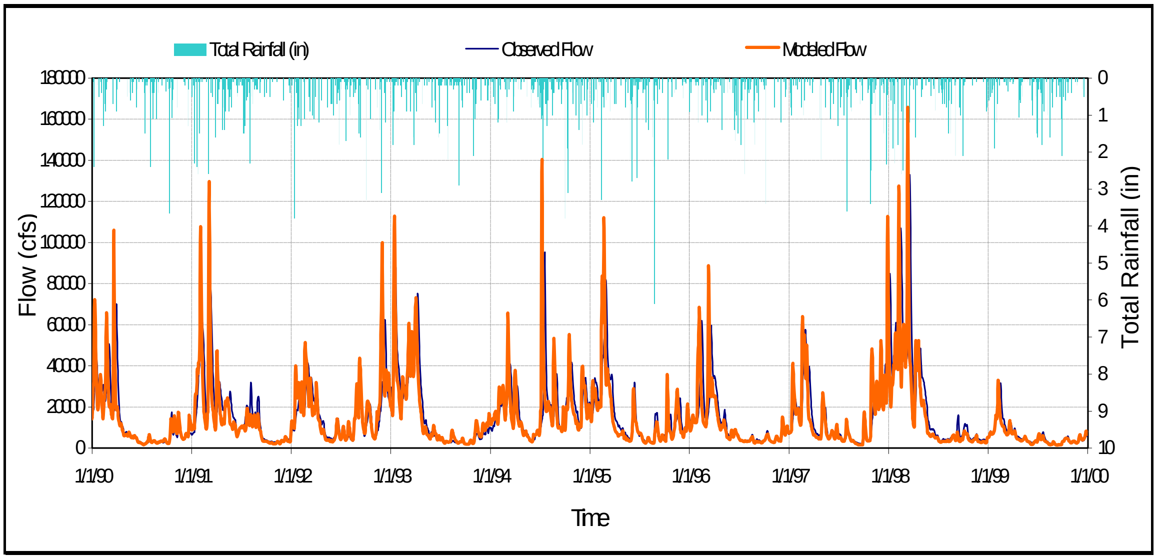


Figure A.21. 10-Year Validation (Daily Flow) at 02226000 – Altamaha River at Doctortown, GA.

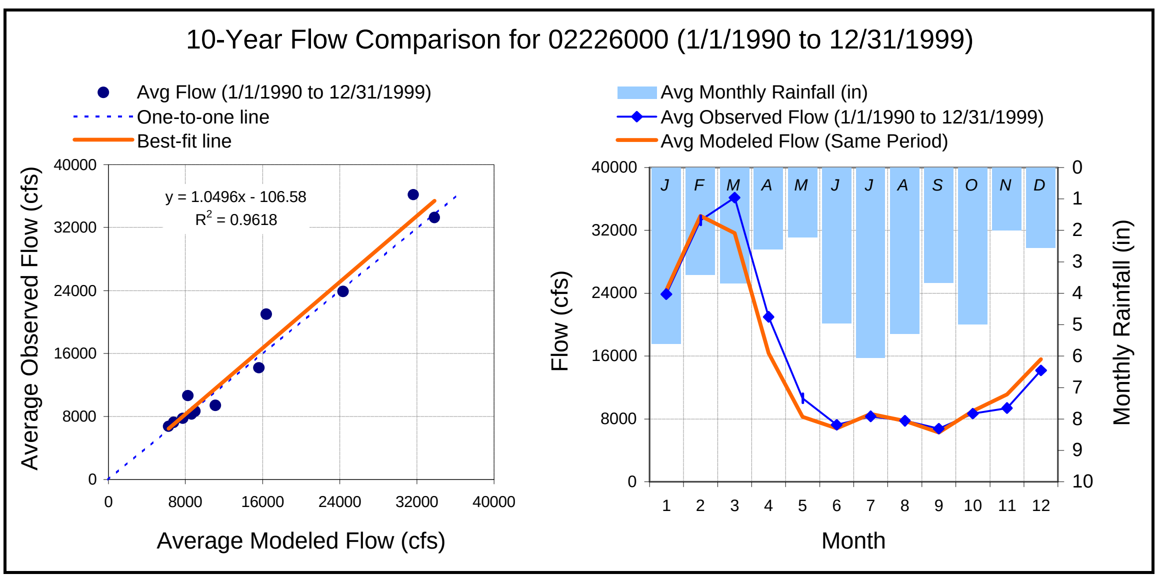


Figure A.22. 10-Year Validation (Monthly Average) at 02226000 – Altamaha River at Doctortown, GA.

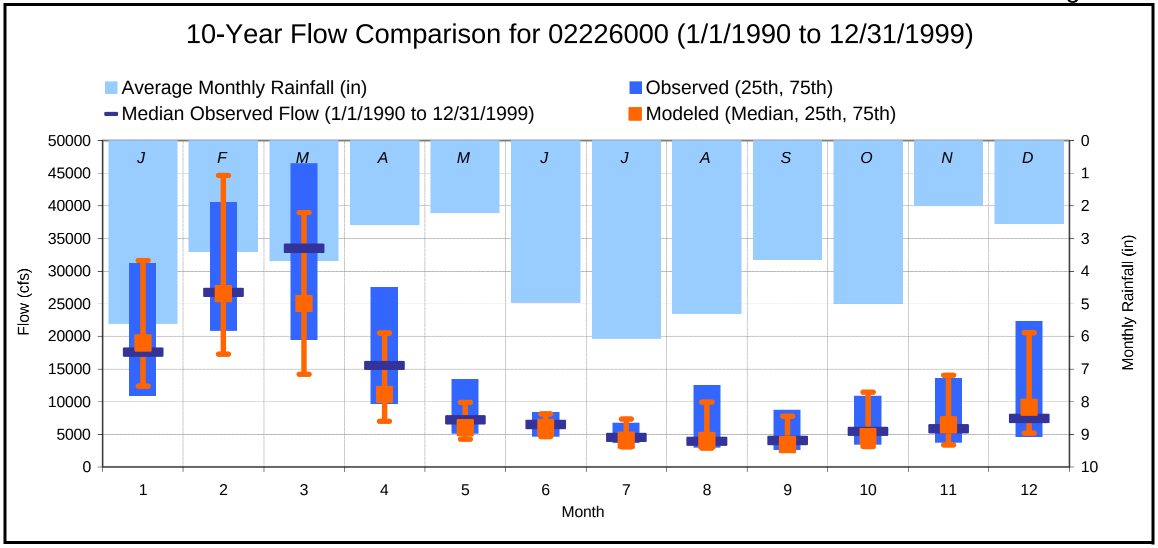


Figure A.23. 10-Year Validation (Monthly Medians) at 02226000 – Altamaha River at Doctortown, GA.

Simulation Name:	02226000	**Simulation Period:**	
		Watershed Area (ac):	8738182
Period for Flow Analysis			
Begin Date:	**01/01/90**	**Baseflow PERCENTILE:**	2.5
End Date:	**12/31/99**	*Usually 1%-5%*	
Total Simulated In-stream Flow:	**148.01**	Total Observed In-stream Flow:	**154.40**
Total of highest 10% flows:	**55.97**	Total of Observed highest 10% flows:	**54.45**
Total of lowest 50% flows:	**22.16**	Total of Observed Lowest 50% flows:	**23.94**
Simulated Summer Flow Volume (months 7-9):	**18.93**	Observed Summer Flow Volume (7-9):	**19.10**
Simulated Fall Flow Volume (months 10-12):	**29.89**	Observed Fall Flow Volume (10-12):	**26.97**
Simulated Winter Flow Volume (months 1-3):	**73.27**	Observed Winter Flow Volume (1-3):	**76.27**
Simulated Spring Flow Volume (months 4-6):	**25.92**	Observed Spring Flow Volume (4-6):	**32.06**
Total Simulated Storm Volume:	**128.79**	Total Observed Storm Volume:	**132.15**
Simulated Summer Storm Volume (7-9):	**14.13**	Observed Summer Storm Volume (7-9):	**13.53**
Errors (Simulated-Observed)		*Recommended Criteria*	Last run
Error in total volume:	**-4.32**	10	
Error in 50% lowest flows:	**-8.01**	10	
Error in 10% highest flows:	**2.72**	15	
Seasonal volume error - Summer:	**-0.90**	30	
Seasonal volume error - Fall:	**9.77**	30	
Seasonal volume error - Winter:	**-4.09**	30	
Seasonal volume error - Spring:	**-23.71**	30	
Error in storm volumes:	**-2.61**	20	
Error in summer storm volumes:	**4.26**	50	

Figure A.24. 10-Year Validation Statistics at 02226000 – Altamaha River at Doctortown, GA.

APPENDIX B:

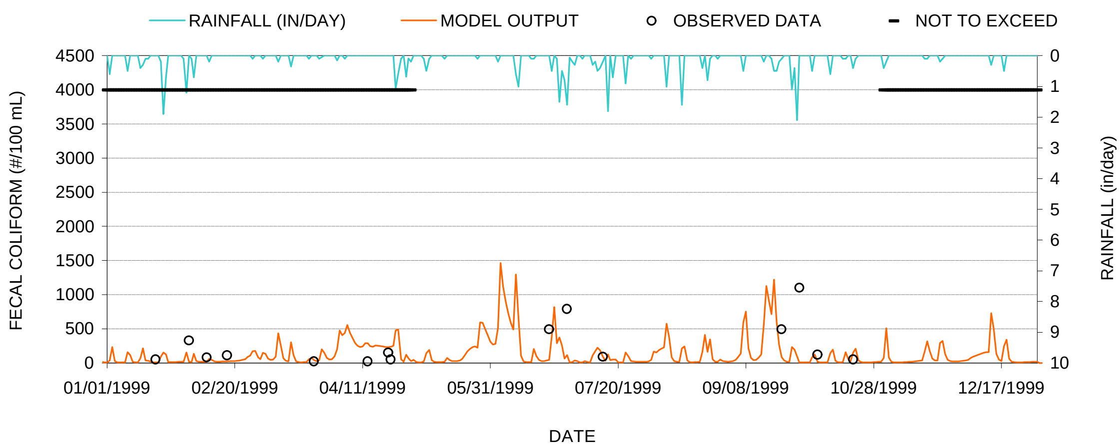
WATER QUALITY MODEL CALIBRATION

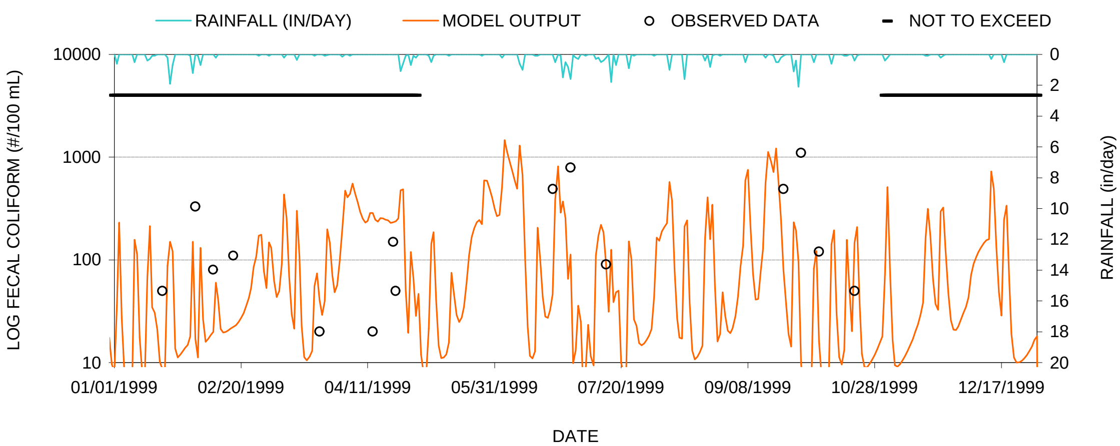
MULTI-YEAR TIMESERIES MODEL VS DATA

STATION: **Doctors Creek, Altamaha Basin**

MODEL RUN: **1**

1 = EXISTING
2 = ALLOCATION 1
3 = ALLOCATION 2



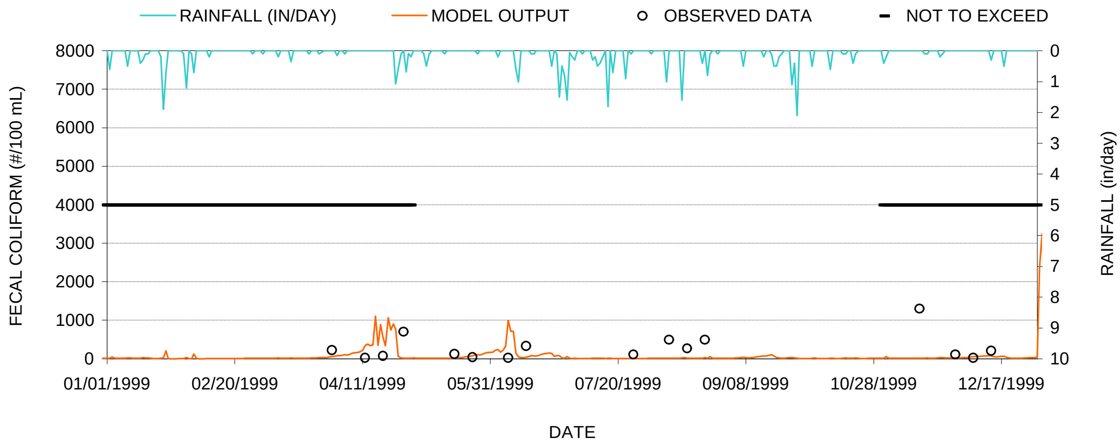


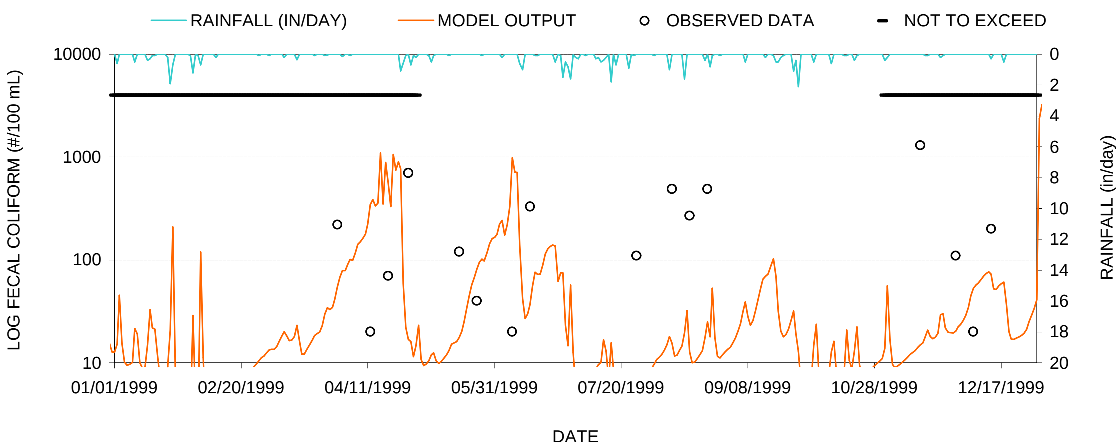
MULTI-YEAR TIMESERIES MODEL VS DATA

STATION:
Goose Creek, Altamaha Basin

MODEL RUN: **1**

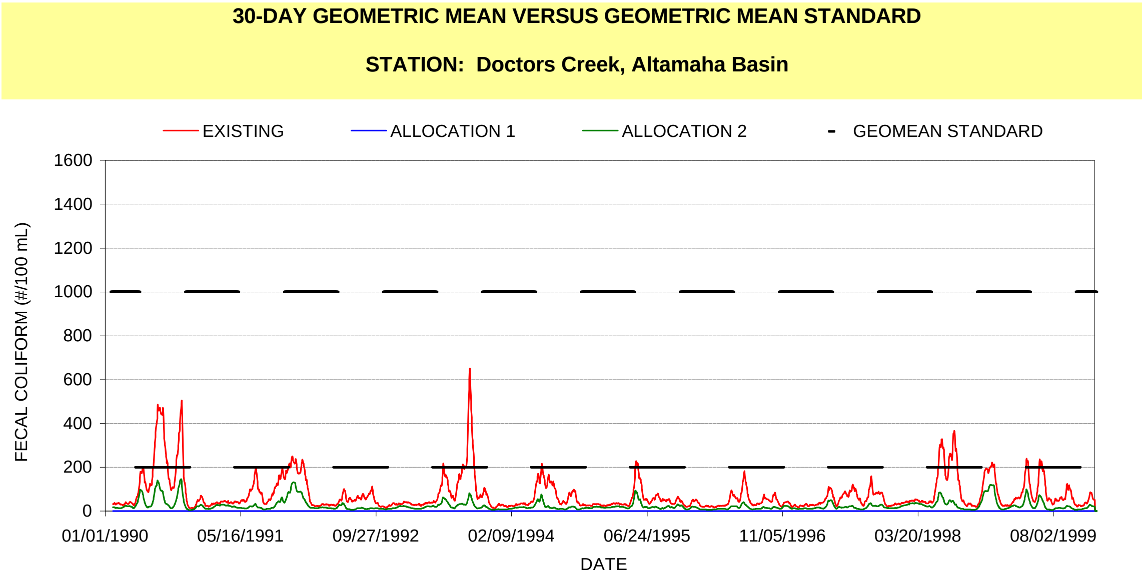
1 = EXISTING
2 = ALLOCATION 1
3 = ALLOCATION 2

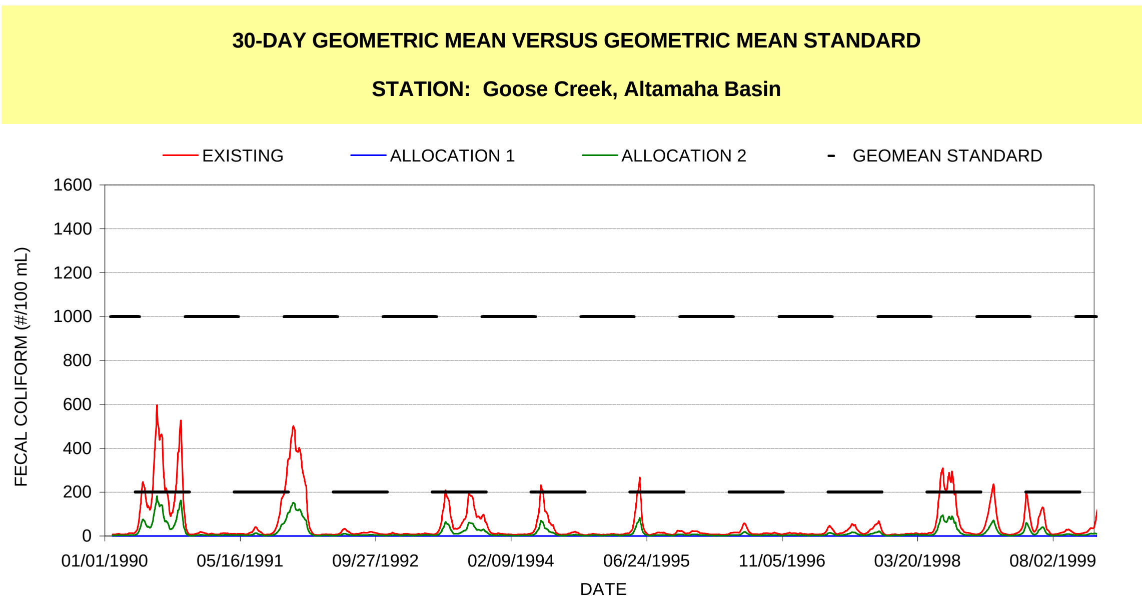




APPENDIX C:

Simulated Fecal Coliform Concentrations
(30-dayGeometric Mean for Existing and TMDL Conditions)


30-DAY GEOMETRIC MEAN VERSUS GEOMETRIC MEAN STANDARD
STATION: Doctors Creek, Altamaha Basin
EXISTING
ALLOCATION 1
ALLOCATION 2
GEOMEAN STANDARD
FECAL COLIFORM (#/100 mL)
1600
1400
1200
1000
800
600
400
200
0
01/01/1990
05/16/1991
09/27/1992
02/09/1994
06/24/1995
11/05/1996
03/20/1998
08/02/1999
DATE


30-DAY GEOMETRIC MEAN VERSUS GEOMETRIC MEAN STANDARD
STATION: Goose Creek, Altamaha Basin
EXISTING
ALLOCATION 1
ALLOCATION 2
GEOMEAN STANDARD
FECAL COLIFORM (#/100 mL)
1600
1400
1200
1000
800
600
400
200
0
01/01/1990
05/16/1991
09/27/1992
02/09/1994
06/24/1995
11/05/1996
03/20/1998
08/02/1999
DATE